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bettering our biology,
one piece at a time



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illuminating space's
darkest mystery

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HOW GRAVITY WORKS

AN END TO BLINDNESS

The miraculous cures
taking shape

PLUS
**ULTIMATE
HOME TECH**
FOR THE SUMMER
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spiders?

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recurring
nightmares?

Why do dogs
bury bones?



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suddenly develops a need for speed.

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WELCOME



Two hundred years ago, the northern hemisphere lost its summer. Rain, snow and frost crept across Europe and North America, leaving disease and famine in its wake. We now know this 'cold snap' had actually started on the other side of the planet. In Indonesia, the supervolcano Mount Tambora had erupted, spitting out a cloud of ash into the stratosphere that would hang there for months soaking up the Sun's warmth.

It was this volcanic winter in June, so the story goes, that kept Mary Shelley and friends indoors for days during a visit with Lord Byron to his house near Lake Geneva. To pass the time, they hosted a ghost story competition and Shelley penned one of the earliest works of science fiction – *Frankenstein*.

Shelley's work was inspired by the discoveries of the time. Public experiments had demonstrated that both animal and human corpses could be shocked into life with electrical current – the science of galvanism. Scientists were beginning to understand that electricity played a vital role in the human body. It's this knowledge that, two centuries on, is now allowing scientists to connect human tissue to machines, creating life-changing prostheses. To find out more on this, and other science that would have inspired Shelley were she alive today, turn to p34.

For more science that sounds like science fiction, turn to p46 where we look at the plans to build a telescope the size of Earth itself. Or head to p68 where Astronomer Royal Martin Rees talks evolution, machine singularities and alien civilisations.

Daniel Bennett

Daniel Bennett, acting editor

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SIMON CROMPTON

Could advances in bionic implants, and gene and stem cell therapies soon make blindness a thing of the past? Science and health writer Simon Crompton brings together the most cutting-edge research. → p61



LORD MARTIN REES

Despite decades of effort, searches for extraterrestrial life have so far come up short. Is something wrong with how we are looking? The Astronomer Royal shares his provocative theory. → p68



MARLENE ZUK

Stan and Olli, two male king penguins, were recently moved to Hamburg Zoo after showing little interest in mating with females. We ask behavioural biologist Marlene Zuk if animals really can be gay. → p22

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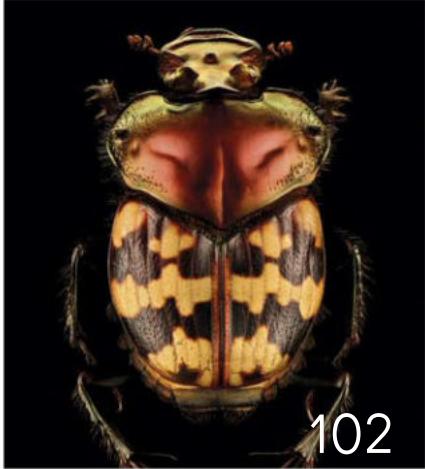
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PHOTOS: LEVON BUSS, JOHNS HOPKINS UNIVERSITY



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Two hundred years after the publication of Mary Shelley's *Frankenstein*, could science finally let us rebuild ourselves?

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By this time next year, we'll have used an Earth-sized telescope to peer into a black hole, solving some mysteries of physics in the process

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Millionaire inventor Bran Ferren has spent five years creating a high tech off-roader. We take a look under the bonnet.

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Can we find a cure for blindness?

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Revolutionary treatments using genes, stem cells and bionics could bring millions of people's worlds back into focus.

Why haven't we found any alien life?

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Think 'aliens' and little green men spring to mind. But according to Lord Martin Rees, aliens are far more likely to be robots.

Summer of sport

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There's plenty for sports fanatics to look forward to over the coming months, so we've picked the best gadgets to help you kick back and enjoy.

Understand gravity

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Gravity is the force that made Isaac Newton and his apple famous. But even today, it continues to throw up some surprises.



76

EYE OPENER

Tower of doom

EMAS NATIONAL PARK,
CENTRAL BRAZIL

Deep in the Brazilian savannah, a termite mound comes alive. Green lights shine into the night – each one the bioluminescent glow of a click beetle larva luring other insects to their death.

On still summer nights, larvae living in the surface layers of the mound poke out of the tunnel in a bid to attract the termites and other flying insects on which they feed. The eerie light trails in this image are a photographic trick, created by zooming out during a long exposure.

Bioluminescence is used by organisms as a form of defence, to attract mates, or – in the case of these click beetle larvae – to catch a tasty meal.

"The glow is produced in organs at the front of each larva's thorax," says Prof Adam Hart, BBC presenter and entomologist at the University of Gloucestershire. "It's created by the action of an enzyme – luciferase – on a light-emitting substance called luciferin. The luciferase acts as a catalyst, allowing oxygen to combine with the luciferin – a process which releases particles of light [photons]."

It's a light show best avoided if you're an insect...

PHOTO: TATIANA CLAUZET

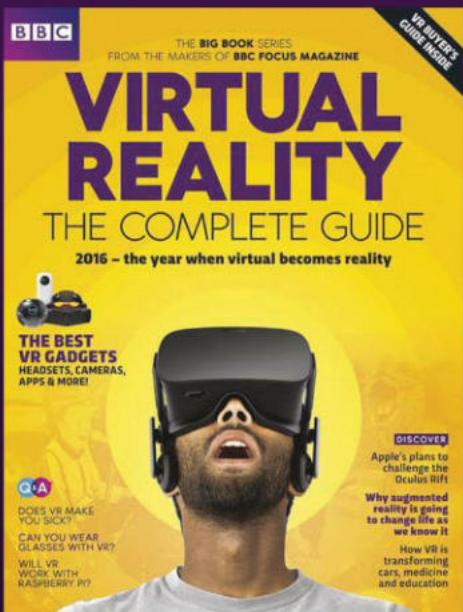




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MESSAGE OF THE MONTH

Limited resources

With reference to Neil Ashton's article about airships (March, p58), airships are beautiful and often look like the future of global transport, but I always wonder whether there will be enough cheap helium to make them economically viable. Liquid helium is vital in medical imaging technology, such as in MRI scanners, and there are concerns that we might reach 'peak helium' in the decades ahead: unlike hydrogen we can't make more of it, and once helium is released it's gone forever. Perhaps *BBC Focus* could provide a story about this issue?

Will De Vere, Melbourne, Australia

• Warnings of helium shortages first crept up in 2012. Since then, a number of projects have been launched to increase supply. We'll keep an eye on it. — Ed



Airships gobble up sparse helium supplies, says Will De Vere

WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins a pair of **Lindy Cromo IEM-75 earphones**, worth £69.98. They include dual drivers for superior sound, and have a stylish black and chrome design. lindy.co.uk

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Seasonal adjustment

In answer to your article 'When does spring begin?' (March, p24), assuming there are four seasons of equal length, we should count forward 6.5 weeks from the winter solstice. This gives 8 February for the start of spring or thereabouts, and 8 May for the start of summer.

Take no notice of what astronomers and meteorologists say, or you will miss the seasons! British schools' summer holidays were timed so the children could work on the farms to help bring in the harvest, nothing much to do with when the summer is – autumn starts around 8 August, which funny enough is when we start to notice leaves falling from the trees, gusty days and warm colours on the landscape from the low Sun.

Paul Buck, via email

Ploughman's hunch

Having read my April copy of *BBC Focus* from cover to cover as usual, one item on p62 got me thinking.

The article describes how an Australian farmer named Brian Fischer ploughed his farmland in spirals to prevent soil erosion.

If Fischer's method really does work, then could it be tried out elsewhere, on a grander scale, where top soil has been left exposed and vulnerable from acts of destruction such as deforestation?

What's the worst that could happen? We'd end up with a few



David Storer thinks we should experiment with ploughing, like farmer Brian Fischer

giddy ploughmen, but at least we'd get to eat. I wonder if the method would have worked on the dust bowls of the US in the 1930s too?

One other thought: what would future alien archaeologists in their orbiting spaceships make of the patterns? My guess is they would simply do the same as today's archaeologists do when faced with something from the past they don't understand – label it 'ritualistic'.

David Storer, Hampshire



Birds of prey can be trained to control drones

Raining cats and drones

Your feature 'Wonders of the drone age' (April, p34) was an interesting read. It made me think of robotic superheroes, and I love the scientific possibilities that

these glorified gadgets are bringing. But even an article as techy as this couldn't brush away my environmental conscience.

I must question the case for drones in the long term. What

happens when, like smartphones, everybody has their own drone? Coupled with pizza delivery drones (could we have those with a contactless card reader, please?) and couriers, what exactly is the state of our visual pollution going to be? Are drone forecasts going to precede the pollen count during the morning weather report?

Although it seems a distant enough problem, I can't help but wonder how we will regulate drone use in the future. But I'll stop droning on about it – for now.

Eve Smith, via email

 The sky is one of our last open spaces. You're right, we should be mindful of it. – Ed

Flip the switch

The trolley problem in your article on driverless cars (March, p72) is a fallacy. It posits that failing to take action by throwing the switch kills several people, while taking action saves them and kills only one.

However, this is illusory: action is taken in both cases. That action is the making of a decision by your grey matter. Whether the decision is to throw the switch or not to throw it, the action of making the decision has been taken first.

Action is therefore unavoidable. So? Action taken, accept it and throw the switch to save the maximum number of people.

However, suppose the half-dozen are elderly and not in great health, while the individual is a 20-year-old footballer who's becoming one of the greats of her generation. What then? Allen Trousdale, via email

Bloody cavemen

Regarding Neanderthals, could you ask Prof Chris Stringer (March, p114) whether blood group incompatibility between Neanderthals and modern humans could have contributed to the demise of the Neanderthals?

Pat McDonnell, Cork

 There are large 'deserts' in our genomes where all traces of Neanderthal DNA has been selected away, while a few areas (such as those concerned with immune responses



If you've got Asian or European ancestry, around 2 per cent of your DNA comes from Neanderthals – can you see yourself in the chap above?

and skin structure) actually show increased levels. Blood group incompatibilities do not seem to be involved, but there is DNA evidence that male hybrid children had significantly reduced fertility compared with the female hybrid children.

– Prof Chris Stringer

Give thorium a chance

I enjoyed 'How we'll keep the lights on?' (March, p36), and I agree that nuclear power gets a worse press than it deserves. However, I found Brian Wang's estimate that using fossil fuels kills 1,000 times more people per terawatt hour compared to nuclear a little incredible.

But I was disappointed that Duncan Geere dismissed thorium reactors. Surely the research and development needed to build liquid thorium reactors would be worthwhile to achieve an energy source that is virtually renewable, and given that it renders meltdown impossible, produces very little (and relatively short-lived) waste.

Mike Follows, West Midlands

 Brian Wang's full study, including information on how he came to these numbers, can be found at: bit.ly/1rVGeYy

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DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

JUNE 2016

EDITED BY JASON GOODYER



LAB-GROWN HUMAN EMBRYOS KEPT ALIVE FOR RECORD TIME

Researchers have grown a human embryo and kept it alive outside the womb for 13 days, shattering the previous record and re-igniting a decades-old ethical debate

Studying young embryos, like this 12-day-old specimen, could improve our understanding of developmental defects and the causes of miscarriage

**"THIS COULD
HELP US
UNDERSTAND
WHAT
HAPPENS
DURING
MISCARRIAGE"**

human embryo alive for 13 days, only stopping to comply with UK law, which places the limit at 14 days. It enabled the researchers to study the molecular processes that occur when a human embryo implants itself into the womb.

"Implantation is a milestone in human development as it is from this stage onwards that the embryo really begins to take shape and the overall body plan is decided. It is also the stage of pregnancy at which many developmental defects can become acquired," said the University of Cambridge's Dr Magdalena Zernicka-Goetz, who led the study. "This new technique provides us with a unique opportunity to get a deeper understanding of our own development during these crucial stages and help us understand what happens, for example, during miscarriage."

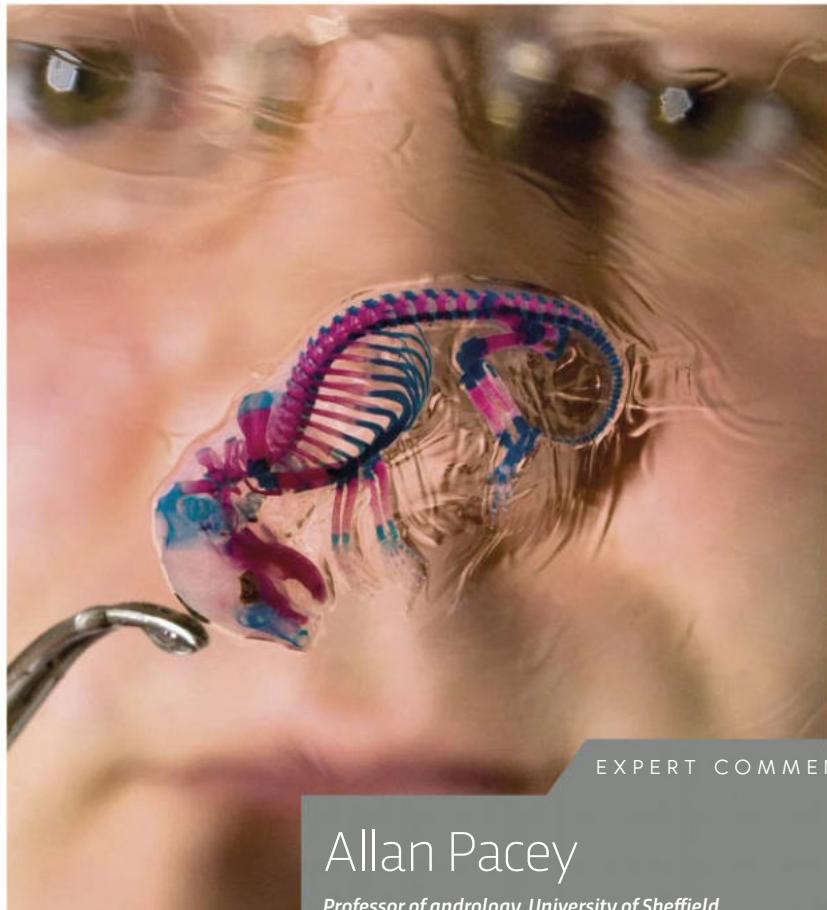
EARLY DAYS

Once an egg has been fertilised by a sperm, it divides to create a clump of stem cells. After about three days the stem cells group together to form something known as a blastocyst. This contains three basic cell types: those that will develop into the body, those that provide nutrients, and those that form the placenta and allow the embryo to attach to the womb. On the seventh day the embryo must implant into the womb to survive.

"Embryo development is an extremely complex process and while our system may not be able to fully reproduce every aspect of this process, it has allowed us to reveal a remarkable self-organising capacity of human blastocysts that was previously unknown," said the University of Cambridge's Marta Shahbazi, who took part in the research.

What is life and when does it begin? It's a fundamental question that has occupied scientists and philosophers for centuries, and one raised once more thanks to results from a groundbreaking embryo study.

Biologists at the University of Cambridge and New York's Rockefeller University have successfully kept a



EXPERT COMMENT

Allan Pacey

Professor of andrology, University of Sheffield

ABOVE: The human embryos were kept alive using methods that had been developed to research mouse embryos, like the one pictured above

BELOW: Study leader Dr Magdalena Zernicka-Goetz says that the study will improve our knowledge of human development



" The framework in which this work has been carried out was first set out in the Warnock Report, published in 1984. This concluded that it was ethical to conduct research on human embryos until day 14 of their development. Parliament agreed with this recommendation when the 1991 Human Fertilisation and Embryology Act was passed. But, until now, this has been a theoretical restriction as no one had the technical means to keep embryos alive in the laboratory much beyond day seven.

To keep the embryos alive in this study, the scientists used methods of culture first tested with mouse embryos. This has allowed them to undertake almost hour-by-hour observations of human embryo development to see how they develop and organise within the first two weeks. This has already provided new information, but in my opinion it is the potential it offers to future research that is most exciting.

There will no doubt be people who will be opposed to this research and may disagree fundamentally with the idea that legitimate and ethical research on human embryos can take place for up to 14 days in the lab. While I respect the strength of their views, this is a framework which was agreed over 30 years ago and I see no reason to revisit that decision. It will not open the door to couples being able to grow babies in the lab – this is not the dawn of a *Brave New World* scenario. But it does open up opportunities to understand the nature of human disease and disability. For that reason, the scientists involved should be congratulated.

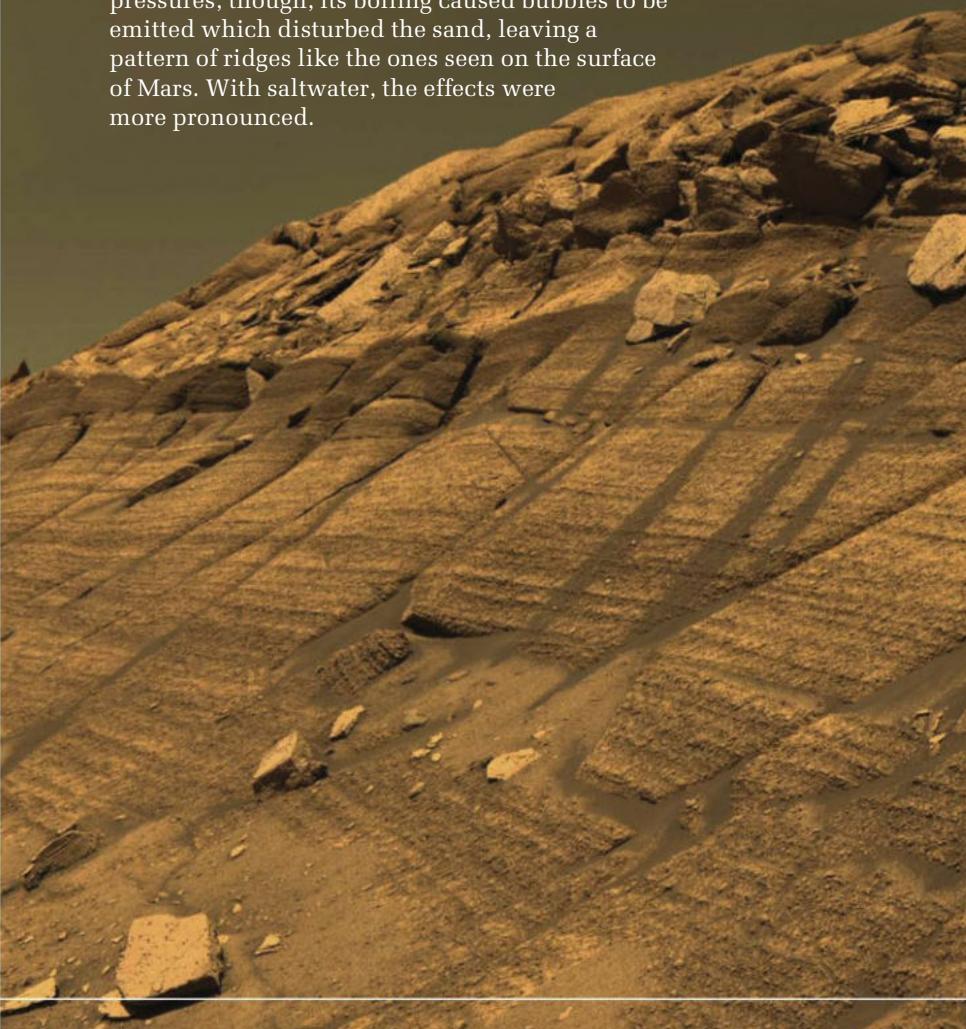
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MARS

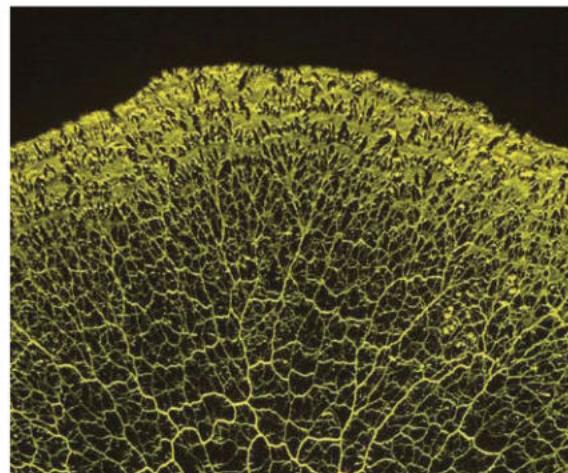
Lines on Mars shaped by boiling water

In 2015, it was discovered that liquid water pools on the surface of the Red Planet during its warmest summer days. However, thanks to the low atmospheric pressure, it boils away almost instantly (the boiling point of water on Mars is just 20°C). Water was therefore believed to play little or no role in shaping the Martian surface. However, an international team of scientists has now shown that even this short-lived boiling water does have a significant geological impact.

The researchers, led by Marion Massé from the Laboratoire de Planétologie et Géodynamique de Nantes (Laboratory of Planetology and Geodynamics of Nantes), recreated two Mars-like environments: one inside a former diving decompression chamber at Mars-like pressure, the other in a cold chamber at terrestrial pressure. When a block of ice melted under 'Earth' conditions, water simply soaked into the sand. When a block of ice melted under Mars-like pressures, though, its boiling caused bubbles to be emitted which disturbed the sand, leaving a pattern of ridges like the ones seen on the surface of Mars. With saltwater, the effects were more pronounced.



Water behaves differently on Mars to Earth, forming ridges like these as it boils away



BIOLOGY

SLIME MOULDS CAN LEARN

Could this be the smartest brainless blob on Earth?
A team of biologists in France has shown that slime moulds are capable of learning, despite having no brain or nervous system.

Slime mould is the name given to over 900 different species of single-celled organisms that cluster together in large numbers and then function as a single being called a plasmodium. Slime moulds exist all over the world, usually feeding on microorganisms that consume decaying plant matter.

In the nine-day experiment at Toulouse University's Centre de Recherches sur la Cognition Animale (Centre for Research into Animal Cognition), three groups of the slime mould *Physarum polycephalum* were confronted with a 'bridge' they needed to cross in order to access food. These bridges were impregnated with either caffeine or quinine, or left untouched. Caffeine and quinine taste bitter but are harmless to the moulds.

The moulds presented with an 'untainted' bridge went straight to the food. Moulds presented with caffeine- or quinine-impregnated bridges were initially reluctant to cross, but having done so safely once were less hesitant the next time. After a few days they would cross quite happily, moving at a faster pace. This is evidence of a type of learning called 'habituation'. Slime moulds that had become habituated to caffeine would not cross a quinine-impregnated bridge, and vice versa.

Memory and the ability to learn are vital survival skills, but it was assumed such abilities required a nervous system. This research shows that such abilities must have evolved earlier than was thought.

IN NUMBERS

<0.001%

New research suggests there may be up to one trillion species of microbes on Earth, meaning that known species account for less than 1/1,000th of one per cent of the total.

709,
190,
040

Daily flow volume, in litres, of the world's shortest river, the Roe River. Given the volume of a human tear is 6.2 microlitres, the whole world couldn't 'cry me a river', let alone Justin Timberlake's ex.

2,325

The number of confirmed exoplanets spotted by NASA's Kepler space telescope so far.

49,000

The age in years of a flake of basalt that was found in Australia. It is thought to be a fragment from the earliest axe with a handle.

HEALTH

MEMORIES LOST TO ALZHEIMER'S MAY BE RECOVERED

Patients in the early stages of Alzheimer's disease often struggle to remember recently learned information, meaning they forget things like important appointments or where they left their keys. But it seems these memories are not lost. They are still filed away in the brain somewhere, they just can't be easily accessed.

Now, researchers at MIT have developed a means of retrieving memories in mice suffering from Alzheimer's. The method relies on optogenetics, a technique that uses light to manipulate genetically modified neurons. Currently it is too invasive to be used in human trials as it involves inserting light-emitting devices into the subjects' brains, but the same underlying principles still apply, the researchers said.

"The important point is this is a proof of concept. That is, even if a memory seems to be gone, it is still there. It's a matter of how to retrieve it," said senior researcher Susumu Tonegawa.

The team took two groups of mice, one genetically engineered to develop Alzheimer's and one healthy. They then placed them into a chamber and gave them a mild electric shock. All of the mice showed fear when put back in an hour later. When placed in the chamber a third time several days later, the Alzheimer's mice acted normally. They had forgotten the shock.

The researchers were then able to bring back the memory of the shock by activating the cells in which the memories were stored. Even when the mice were put into an unfamiliar chamber, they showed fear when the cells associated with the shock were activated.

"Short-term memory seems to be normal, on the order of hours. But for long-term memory, these early-Alzheimer's mice seem to be impaired," said lead researcher Dheeraj Roy. "Directly activating the cells that we believe are holding the memory gets them to retrieve it. This suggests that it is indeed an access problem to the information, not that they're unable to learn or store this memory."



PHOTO: JOSE-LUIS OLIVARES/MIT



ILLUSTRATOR: RAJA LOCKEY

THEY DID WHAT?!**MICE BRED TO STUTTER****What did they do?**

A team at Washington University School of Medicine bred mice with a mutated strain of Gnptab. A mutated version of this gene has been linked to stammering in humans.

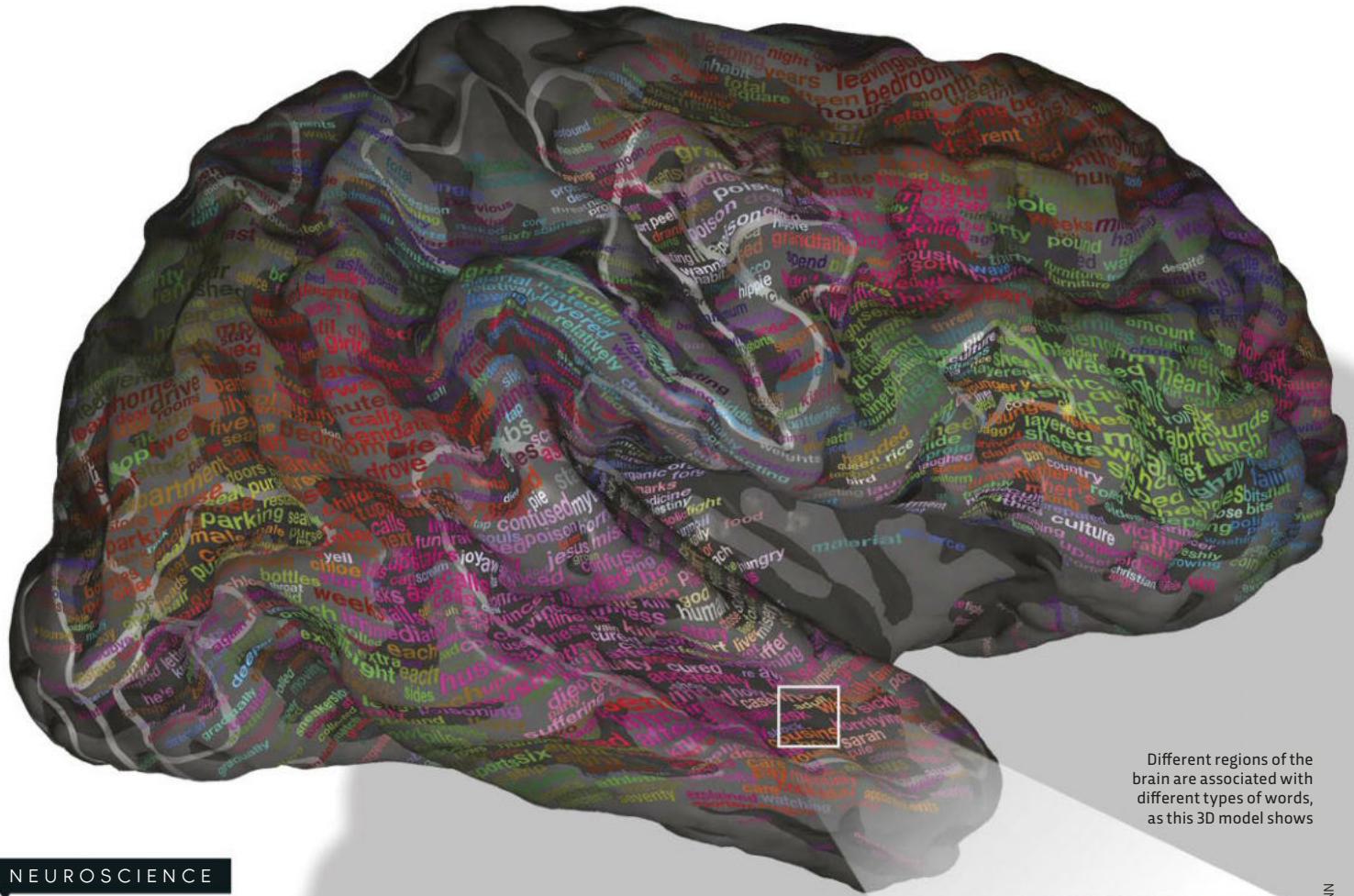
What did they find?

The mice carrying the mutation paused for longer between squeaks and repeated the same sounds more often than the non-carrying mice. They also produced a smaller variety of sounds than mice without the mutated gene.

Why did they do that?

Although speech is an incredibly complicated process, the finding could provide researchers with a method of further studying the roles of genes in stammering. The end goal would be the development of effective treatments for sufferers.





Different regions of the brain are associated with different types of words, as this 3D model shows

NEUROSCIENCE

NEUROSCIENTISTS CREATE A 'WORD MAP' OF THE BRAIN

It's a dictionary with a difference. Researchers at University of California Berkeley have created a 3D map showing how the brain stores and processes language. It's hoped the research could lead to new treatments for strokes or motor neurone disease.

The research involved subjects lying in an fMRI scanner while listening to hour-long story-based podcasts. This generated a second-by-second 'map' of bloodflow in the brain, enabling the scientists to build a picture of which brain regions are activated in response to particular words.

Around 150 different regions in the brain are thought to be involved in linguistic processing. The new research reveals that words describing particular things, such as emotions, visual

"THESE
BRAIN MAPS
ARE SO
EXCITING
AND HOLD
SO MUCH
POTENTIAL"

characteristics or quantities, are linked to their own distinct regions. While there was variation between individuals, patterns of brain activity proved surprisingly consistent from one research subject to another.

"Our semantic models are good at predicting responses to language in several big swaths of cortex," said lead researcher Alex Huth. "But we also get the fine-grained information that tells us what kind of information is represented in each brain area. That's why these maps are so exciting and hold so much potential."

The next step will be to repeat the experiments with a much larger sample size, as the initial research involved just seven subjects.



PHOTOS: ALEXANDER HUTH, SHEIKH ZAYED INSTITUTE FOR PEDIATRIC SURGICAL INNOVATION, UNIVERSITY OF BONN

MEDICINE

Could your next surgeon be a robot?

This is cutting-edge stuff. A team at Children's National Health System in Washington has created a robot surgeon that can outperform its human counterparts.

Acting under the supervision of a human consultant, the Smart Tissue Autonomous Robot (STAR) successfully stitched together the intestines of both live and dead pigs. And although it took longer than a human surgeon, at 35 minutes compared to eight, STAR produced stitches that were more evenly spaced, which helps to promote healing and prevents leakage.

"Our results demonstrate the potential for autonomous robots to improve the efficacy, consistency, functional outcome and accessibility of surgical techniques," said surgeon Peter C Kim. "The intent of this demonstration is not to replace surgeons, but to expand human capacity and capability through enhanced vision, dexterity and complementary machine intelligence for improved surgical outcomes."

The robot uses a combination of infrared and 3D light field imaging systems along with an intelligent algorithm. These allow it

to track movement of tissue and make adjustments in real time.

"Until now, autonomous robot surgery has been limited to applications with rigid anatomy, such as bone cutting, because they are more predictable," said technical lead Axel Krieger. "By using novel tissue tracking and applied force measurement, coupled with suture automation software, our robotic system can detect tissue motions in real time and automatically adjust."

Now that the system has been successfully tested, the team plans to improve the sensors and miniaturise the tools. With the right backing, some of the tech could make its way into operating theatres in the next two years.



With a human surgeon supervising, the robot doctor successfully performed procedures on pigs



THE DOWNLOAD

Brown fat

What's that? A sleazy 70s funk band perhaps?

Afraid not. It's a so-called 'good' fat. Unlike white fat, which stores calories and can lead to the dreaded spare tyre, brown fat burns energy to produce heat.

Tell me more.

Brown fat is difficult to find and study and its exact role is still being figured out. It's found in different areas in people's bodies. It is activated by cold and may act as a kind of internal jacket to keep us warm.

Any new developments?

A team at the University of Bonn has found that when there are low levels of miRNA92a, a type of molecule responsible for the coding and expression of genes, brown fat cells burn more energy. The finding may help researchers develop drugs that kick-start brown fat's energy burning activity.

If we can figure out how to manipulate brown fat, could we all be turned into svelte waifs?

Not exactly. There are lots of factors involved in obesity but the finding could eventually provide doctors with a useful tool to aid fat loss.



Brown fat burns energy, unlike more familiar white fat

ZOOLOGY

"I think we're just seeing the tip of the iceberg in terms of whether there's same-sex behaviour"

Stan and Olli, a pair of male penguins, were recently moved from Berlin to Hamburg Zoo after attempts to mate them with females failed. So can animals be gay? We asked behavioural biologist Prof Marlene Zuk

How common is homosexual behaviour in nature?

We really don't know. I think we're just seeing the tip of the iceberg in terms of whether there's same-sex behaviour. Incidentally, that's a term I like better than 'homosexual', in part because homosexual is used to refer to a variety of things in people: sexual orientation and sexual preference, what people want to do, the kinds of partners they have. In animals, we really don't know anything about their motivations. Animals showing same-sex behaviour aren't necessarily pairing for life. Bonobos have sex between

BELOW: Stan and Olli, two male king penguins at Hamburg Zoo, only have eyes for each other

females and it seems to serve a function of defusing social tension in interactions. Are they gay? No, they're just doing what they're doing. Sex isn't always about reproduction. There are circumstances in which sexual behaviour has a function that isn't going to result in sperm meeting egg.

One member of another famous 'gay' penguin couple, Roy and Silo of New York Central Park Zoo, ended up mating with a female. Were the German zookeepers too hasty in relocating their penguins?

These are captive animals and their behaviour is already being controlled... it's not like they're in the wild to begin with. So I think it's a little bit pointless to speculate about 'Shouldn't we leave them the option of reproducing later?' because you've already radically disrupted what their behaviour would have been like. It illustrates something that's clear about a lot of birds: if you give them potential partners then they'll often pair off with them, and sometimes those partners are members of the same sex.

Are we in danger of applying our values to animals? Absolutely. There are certain aspects of animal





ABOVE: King penguins are just one bird species that has shown same-sex behaviour

BELOW: Prof Marlene Zuk says that we don't know anything about animals' motivations, so we can't compare their behaviour to ours



ILLUSTRATION: RAJA LOCKEY

behaviour that people pick up on as being particularly significant, as if something animals do is really important for what humans can or can't, should or shouldn't do. People have argued it both ways, and historically that's always been true. We can actually make up our own minds about what we think is appropriate to do, without using penguins as role models.

Are there biological benefits to same-sex behaviour?
It's hard to know. One possibility is that individuals who engage in even a temporary pairing with a member of the same sex might end up more likely to be in an opposite sex pairing later on. I'm quite interested in a system like that in albatrosses, where there are a lot of female-female pairs. Other people have suggested that a gene influencing sexual orientation in humans could be fostered if it's linked with a gene that renders females more fertile. People seem to want to have a single answer, that there are gay penguins for the same reasons that there are gay bonobos or whatever. Whether you want to call it 'homosexual' behaviour or not, it encompasses a lot of different patterns and a lot of different kinds of animals.



LOVING MOTHERS

If you want your kids to be a success, forget piano lessons and ballet. All you need is love. The children of nurturing mums have increased brain growth in areas associated with learning and memory, a University of Washington team has found.

RESIDENTS ON FLIGHT PATHS

For those living on a flight path, it can be too noisy to enjoy a garden barbecue. But help may be at hand. A team at the University of Minnesota has found patterns in the airflow of jet engines that are responsible for the deafening noise. The discovery could lead to the development of near silent jets.

GOOD MONTH

BAD MONTH

TRAVELLING SALESMEN

Ever wonder why it's more difficult to sleep in an unfamiliar bed? Researchers from Brown University have found that one hemisphere of the brain remains partially awake on the first night of sleeping in a new place.

PAMPERED POOCHE

Put down the chihuahua! Close physical contact can make dogs seriously anxious, researchers at the University of British Columbia have found. The effect is due to the dogs feeling trapped as their natural instinct to run away from trouble kicks in.



SPACE

NEARBY EXOPLANETS MAY BE OUR BEST CHANCE OF FINDING EXTRATERRESTRIAL LIFE

It seems habitable planets are like buses: you spend all of your time waiting for one and then three come along at once.

An international team of astronomers from MIT and the University of Liège has spotted three planets orbiting a small supercool star, just 40 light-years away in the constellation of Aquarius. The sizes and temperatures of these worlds are similar to those of Earth, making them amongst the best targets found so far for the search for life outside the Solar System, the astronomers say.

“These planets are so close, and their star so small, we can study their atmosphere and composition, and further down the road, which is within our generation, assess if they are actually inhabited,” said researcher Julien de Wit. “All of these things are achievable, and within reach now. This is a jackpot for the field.”

Earth-sized exoplanets are often tricky to study as they are relatively small and can easily be overwhelmed by light from their host star,

making them difficult to see in detail. But these new planets are orbiting a fainter dwarf star that emits radiation in the infrared wavelength, so they are much easier to view in detail.

The planets were discovered using TRAPPIST (TRAnsiting Planets and PlanetesImals Small Telescope), a 60cm telescope operated by the University of Liège, based in Chile.

Due to their size and proximity to their ultracool host star, all three planets could potentially have regions with temperatures suitable for sustaining liquid water and life.

“Now we have to investigate if they’re habitable,” de Wit said. “We will investigate what kind of atmosphere they have, and then will search for biomarkers and signs of life. We have facilities all over the globe and in space that are helping us, working from UV to radio, in all different wavelengths, to tell us everything we want to know about this system. So many people will get to play with this.”





WHAT WE LEARNED THIS MONTH

LABRADORS ARE PROGRAMMED TO BE CHUBBY

Labs are among the tubbiest of dogs – almost two-thirds of them are overweight. Researchers have found this may be due to a mutant version of the gene POMC, which helps switch off hunger following a meal.

OLDER PEOPLE FEEL PAIN MORE

Next time your nanna moans about her aches and pains, you might want to show a bit of sympathy. A study at the University of Florida has found that inflammation following an injury occurs faster and lasts longer in older people.

STIS COULD BE RESPONSIBLE FOR HUMAN MONOGAMY

Canadian researchers used computer models to emulate the evolution of sexual relations as societies grew from small groups of hunter-gatherers to larger agricultural settlements. They found that as partner availability increased, so did STI prevalence. This led to a drive towards humans taking just one sexual partner. How romantic.

IT'S EASIER TO REMEMBER SOMETHING IF YOU DRAW IT

Making sketches of things you need to remember can help you to recall them twice as well, researchers at the University of Waterloo have found. It might make shopping lists a bit more interesting too.

PALAEONTOLOGY

Earliest plant-eating marine reptile discovered in China

This bizarre hoover-beaked beastie is *Atopodentatus unicus*, a crocodile-sized marine reptile that patrolled the seas of southern China 242 million years ago, making it the earliest plant-eating marine reptile ever discovered.

Fossils of the animal were first found in 2014, but as the head was poorly preserved the nature of its jaw was impossible to figure out. Now, after the discovery of two more complete fossils, an international team of researchers from China, Scotland and the US have solved the riddle.

"It's a very strange animal," said researcher Olivier Rieppel. "It's got a hammerhead, which is unique. It's the first time we've seen a reptile like this."

The animal, whose name means 'unique strangely toothed', lived up to its moniker. It had a row of peg-like teeth running around its mouth with bunches of needle-like teeth further inside.

To get to the bottom of how the reptile fed, the team used an unconventional material: Play-Doh.

"To figure out how the jaw fitted together and how the animal actually fed, we bought some children's clay, kind of like Play-Doh, and rebuilt it with toothpicks to represent the teeth," said Rieppel. "We looked at how the upper and lower jaw locked together, and that's how we proceeded and described it."

After analysing the structure and shape of the model, the team concluded that the unusual jaw of *A. unicus* would have helped it eat plants. "It used the peg-like front teeth to scrape plants off rocks on the sea floor, and then it opened its mouth and sucked in the bits of plant material. Then, it used its needle-like teeth as a sieve, trapping the plants and letting the water back out, like how whales filter-feed with their baleen [comb-like structures in the mouth]," said Rieppel. "The jaw structure is clearly that of an herbivore. It has similarities to other marine animals that ate plants with a filter-feeding system, but *Atopodentatus* is older than them by about eight million years."

BELLOW: No, it's not a novelty vacuum cleaner – it's an ancient marine reptile called *Atopodentatus unicus*. That jaw shape helped it to scrape up plants from the seabed



Ultracool stars, like this red dwarf in the Aquarius constellation, only emit faint light, making it easier to observe any planets nestled around it

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FINGERTIP CONTROL

Researchers create most advanced prosthetic hand yet

This robotic hand was created by a team led by Zhe Hu of Yale University and Emanuel Todorov of the University of Washington. It's already incredibly human-like in its abilities, and is able to pick up very small objects – but now the researchers want to go one step further and give it real human tendons and skin.

To create the hand, the team 3D-printed exact replicas of the bones from an actual human hand, then joined them together using a polyethylene fibre called Spectra which is both strong and flexible. To give the hand realistic contours, laser-cut sheets of rubber were used, but now the researchers hope to use the hand as a frame on which to grow real human tissue.

If it works, the obvious application would be as a prosthetic hand for people who've lost one. But since the hand can also be operated remotely using a sensor-equipped glove, it could also prove a valuable tool for anyone undertaking delicate engineering tasks in hostile environments, such as astronauts or nuclear power plant personnel.



IS THIS THE FUTURE OF FURNITURE?



These days, connected technology isn't just smart kettles and intelligent fridges...

Lift-Bit

Developed by Italian design house Carlo Ratti Associati, Lift-Bit brings modular furniture into the Internet of Things age. The system consists of hexagonal stools which can be put together however you like, and raised or lowered in height (within a range of 480-780mm) using an accompanying tablet app or, thanks to built-in sensors, simply by waving a hand over them. So what's been a sofa all day can convert into a bed at night, for example. But such convenience doesn't come cheap: each stool will cost around £650 when they go on sale later this year, so enough to make a double bed will set you back around £8,000. carloratti.com



LG Styler

Available now for around £1,300, the Styler 'clothing care system' steams your clothes, eliminating expensive trips to the dry-cleaner's and the hassle of ironing clothes. There's a rail for large garments, a rack for smaller items and a built-in trouser press, while aroma capsules help keep clothes smelling fresh as a daisy. lg.com



Lian-Li DK-04 desk

This standing desk brings new meaning to the term 'desktop computer'. Inside its chassis lies a PC motherboard with enough slots and bays to satisfy any builder (including support for eight disk drives), while USB and audio ports sit on the front panel. Add a monitor and away you go. lian-li.com



Smarttress

Worried that your partner's cheating? Spanish company Durmet will help you find out, by using a Wi-Fi mattress. Pressure and velocity sensors in the Smarttress detect "suspicious activity" and then send alerts to your phone. And yes, it's a terrible idea – relationships need to be based on trust, not on high-tech spyware! smarttress.com

Robots take stock

ROBOTICS

Shelf-employed robots are coming

More and more jobs can be done by machines these days, and the latest occupation put on the endangered list by robotics engineers is that of the supermarket stocktaker.

Developed by Canadian firm 4D Retail Technology Corp, the Space Genius is a Segway-based robot that can inventory an entire supermarket in less than an hour. It uses AI to navigate its way around, while digital cameras and object-recognition software help it determine what is on the shelves.

For consumers, this means there's much less chance of the items you want being unavailable – but the arrival of Space Genius is likely to be greeted with rather less enthusiasm by existing supermarket staff.



IMAGING

All-seeing eyemask



Locating survivors in a burning building just got easier, thanks to this new fireman's mask with built-in thermal imaging

American company Tyco, which makes fire and security products, has unveiled 'Scott Sight' – a firefighter's face mask with built-in thermal imaging.

These days, firefighters routinely use thermal imaging to locate people who are in need of rescue from smoke-filled rooms, but until now this has meant carrying bulky thermal imaging cameras into the emergency zone, which obviously leaves them with one less hand for fighting fire and rescuing people. Scott Sight solves that problem by placing a thermal imaging camera on the front of the mask, and a small heads-up display inside it. The camera and display will run for up to four hours on a single charge, and the system can be calibrated for different ambient temperatures, which is kind of useful when you're inside a burning building.

We're actually quite surprised it's taken this long for such a device to arrive. But better late than never, eh?

COMPUTING

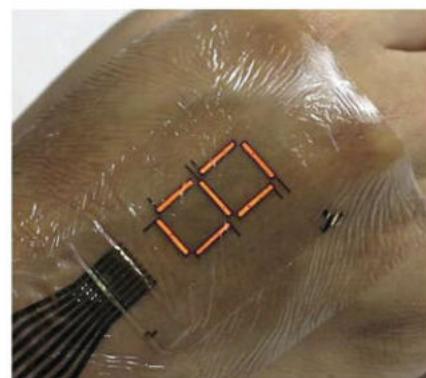
A screen on your skin

Scientists in Japan have built an early prototype of a system that could one day turn your skin into a computer display. The device consists of polymer LEDs that are just three micrometres thick and equipped with organic photodetectors. In the proof-of-concept trial shown here, the University of Tokyo researchers mounted the LEDs on a flexible rubber substrate and connected them to a sensor that measures blood oxygen levels, and then attached them to a human hand using, essentially, clingfilm. The effect, if you can ignore the clingfilm at least, is somewhat akin to having an LED tattoo.

It's hoped that, going forward, the technology will be used to make

wearable devices much less bulky and intrusive. Before long, you could be ditching your smartwatch and getting email notifications right on your wrist, while the technology could also be used to replace the heads-up displays currently used by military and emergency services personnel.

Once perfected, the new technology could turn your skin into the ultimate portable display



WANTED!

HAVE A BALL

PLAYDATE

Pets left home alone often get bored while you're at work, which can lead to you coming home to find your Rhodesian ridgeback has chewed the three-piece into a 274-piece! Help is at hand in the form of this remote-controlled ball that lets you play with your pet from anywhere, at any time. PlayDate hooks up to your domestic Wi-Fi and can be controlled via an Android/iOS app or online, while the built-in 160° camera, microphone and speaker let you see what's going on and interact with your pet.

\$249 (£170 approx), startplaydate.com



YOUR SIX-LEGGED FRIEND

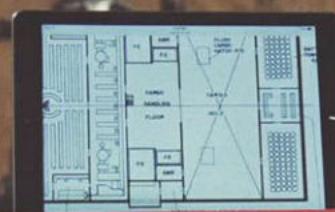
DFROBOT ANTBO

Meet Antbo, a build-it-yourself robot for kids that aims to spark an interest in engineering, robotics and programming. Youngsters put the robot together and can then program it to navigate mazes, respond to voice commands or even do battle with other Antbos. It's programmed using MIT's Scratch, Arduino IDE or DFRobot's own visual programming language WhenDO, and once you've mastered the basics you can add extra sensors via expansion packs.

\$69 (£47 approx), dfrobot.com

21ST-CENTURY TOOLBOX

COOLBOX



Take the pain out of DIY with this high-tech powered toolbox, which features a detachable LED lamp, a magnetic lid to keep screws, bolts and washers from going astray, a flip-out whiteboard for quickly jotting down measurements, three plug

sockets, two USB ports and a stand for your tablet that'll be handy if you're following instructional videos on YouTube. It's waterproof and on wheels, and built-in Bluetooth speakers and a clock help to seal the deal.

\$199 (£137 approx), coolbox.io



BREATHE EASY

DYSON PURE COOL LINK

It's been available in Japan for a while, but now Dyson's domestic air purifier is coming to the UK, in both desktop and floorstanding models. An impeller similar to that found in extractor fans draws in air and a 360° glass HEPA filter removes allergens and other

impurities, capturing particles as small as 0.1 micrometres in diameter before expelling clean air through the fan. An accompanying Android/iOS app lets you control the filter's operation and monitor your home's air quality over time.

£350/£450, dyson.co.uk



APP FEED



ChemCaper

A chemistry-based game in which you battle to save the world by gathering chemicals and making reactions happen. **£5.99, iOS/Android**



Revolution

Gives you control over notifications on your Android device, such as bundling all notifications from one app into one. **Free, Android**



iPlayer Kids

A version of the iPlayer app just for little ones, so you can leave them to watch *Horrible Histories* and be sure they won't wander into *The Tudors*. **Free, iOS/Android/Kindle Fire**



Got an axe to grind?



COOL STRUMMER

MI GUITAR

If you dream of grinding out power chords like Tony Iommi but have all the manual dexterity of Captain Hook, the MI Guitar is for you! Your right hand strums strings as normal, but your left hand simply presses buttons; on each fret there's one for the root chord plus five more for other chord variants, and you use these to jam along to 'sheet music' on an accompanying app. Yes, it's a toy, not a guitar training aid – but it looks like one hell of a lot of fun.

\$299 (£200 approx), magicinstruments.com

A RUDE AWAKENING

PAVLOK SHOCK CLOCK

Do you regularly sleep through your alarm clock in the mornings, despite having bought one that can be heard two streets away? Then Shock Clock could be the answer. It's a wristband that first vibrates, then beeps... then delivers an electric shock to rouse you from your slumbers. The idea is that, in true Pavlovian fashion, your body will want to avoid the shock and so learn to wake you up naturally at the appropriate hour.

\$99 (£70 approx), pavlok.com



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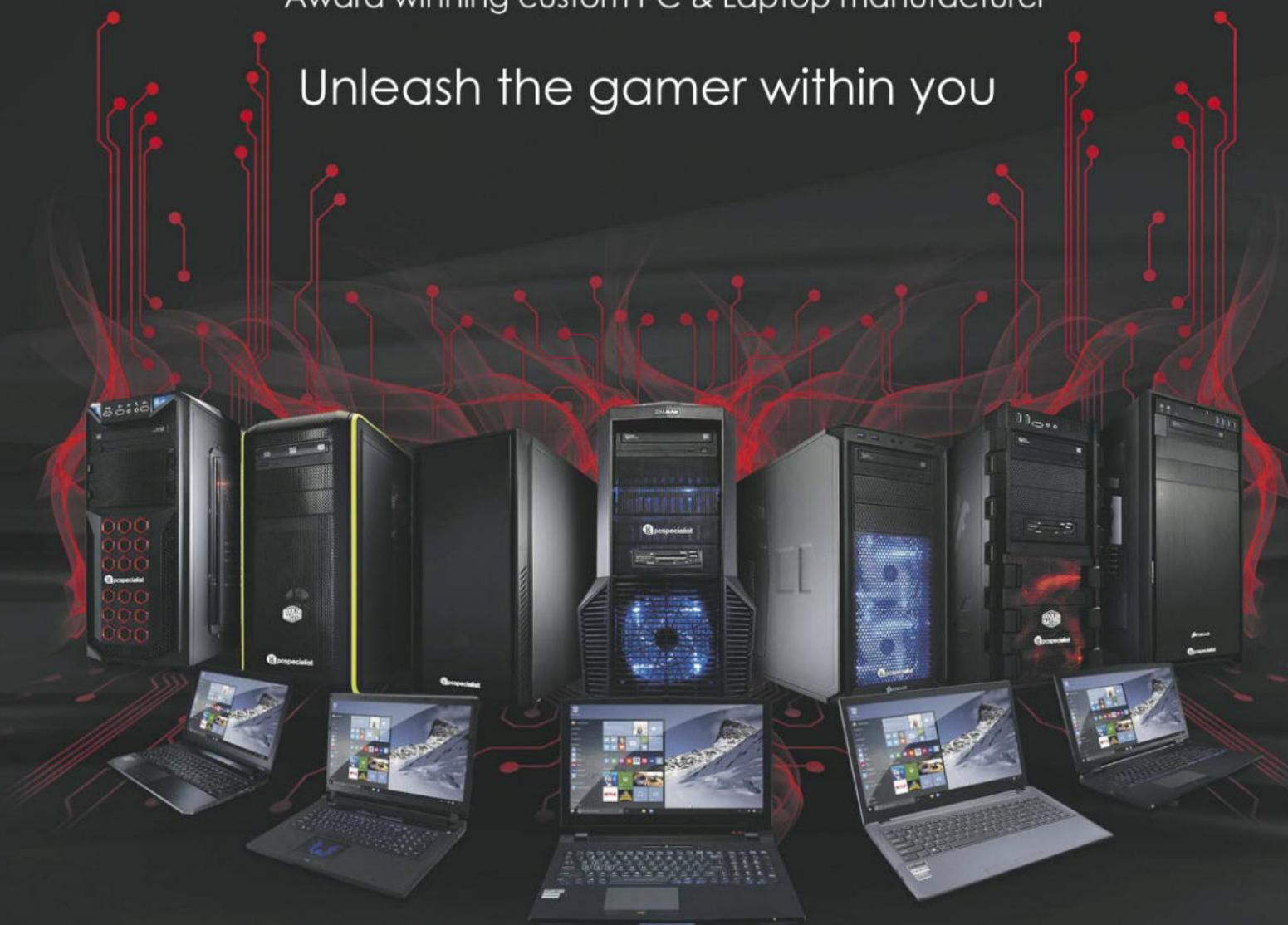




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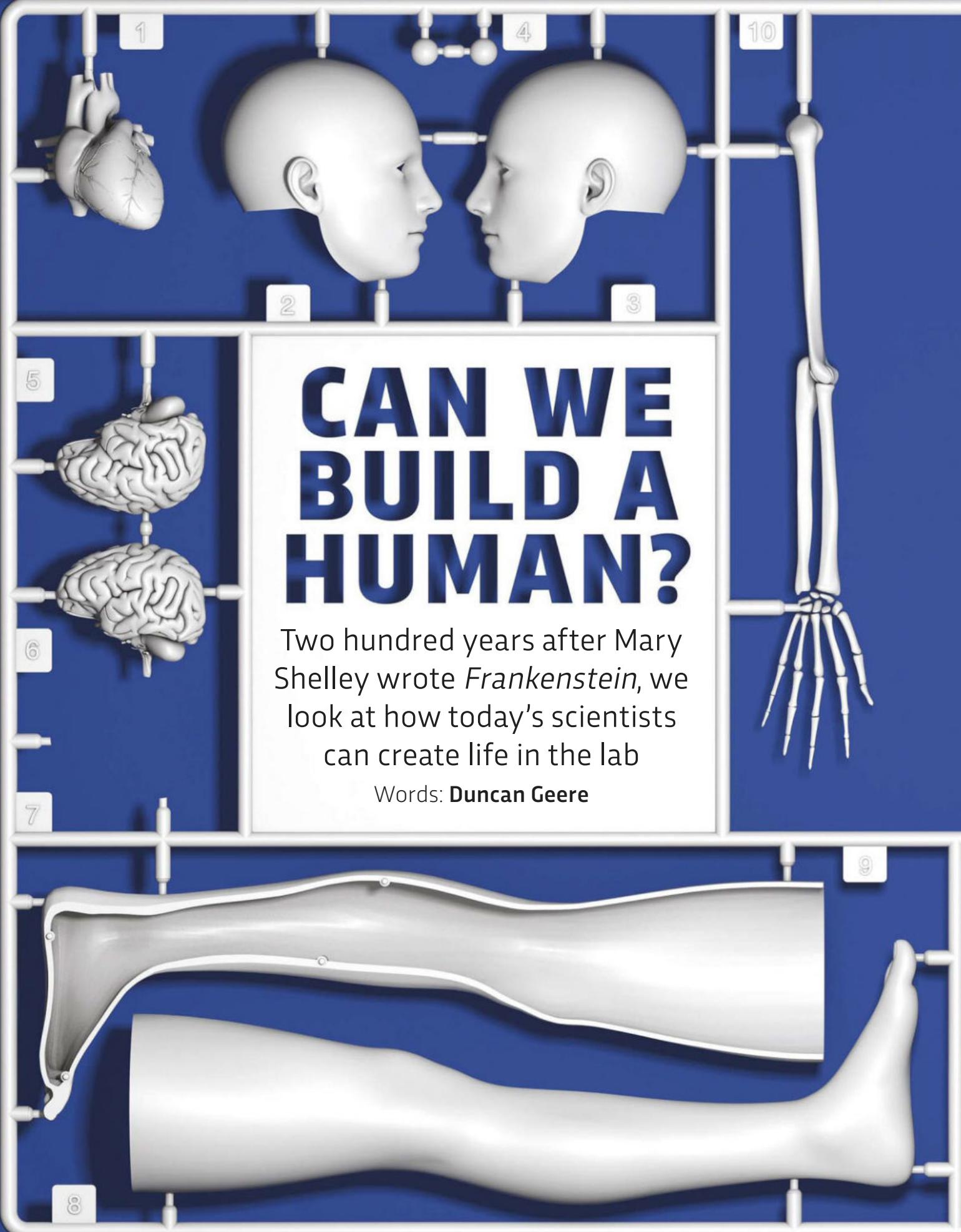
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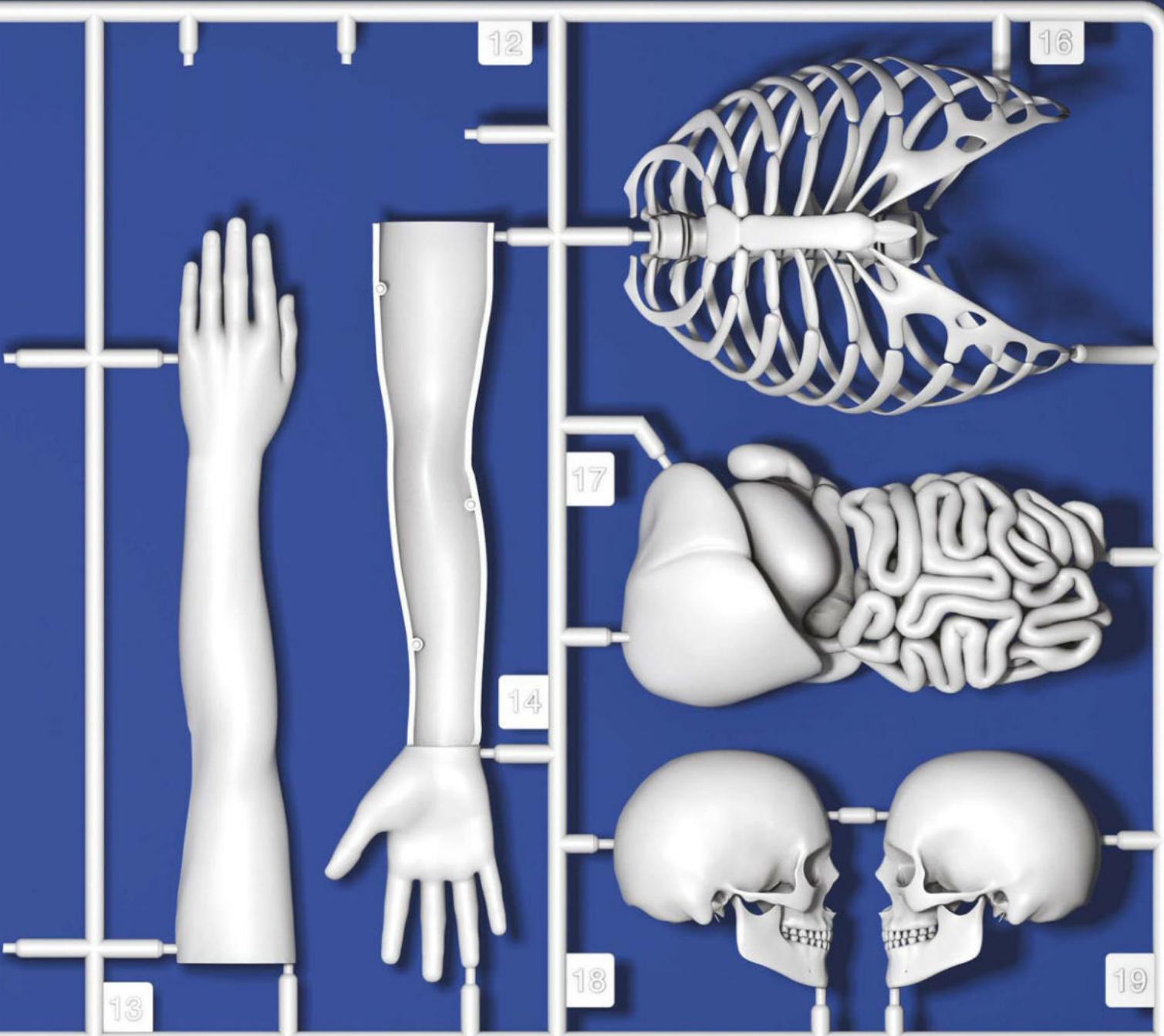
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CAN WE BUILD A HUMAN?

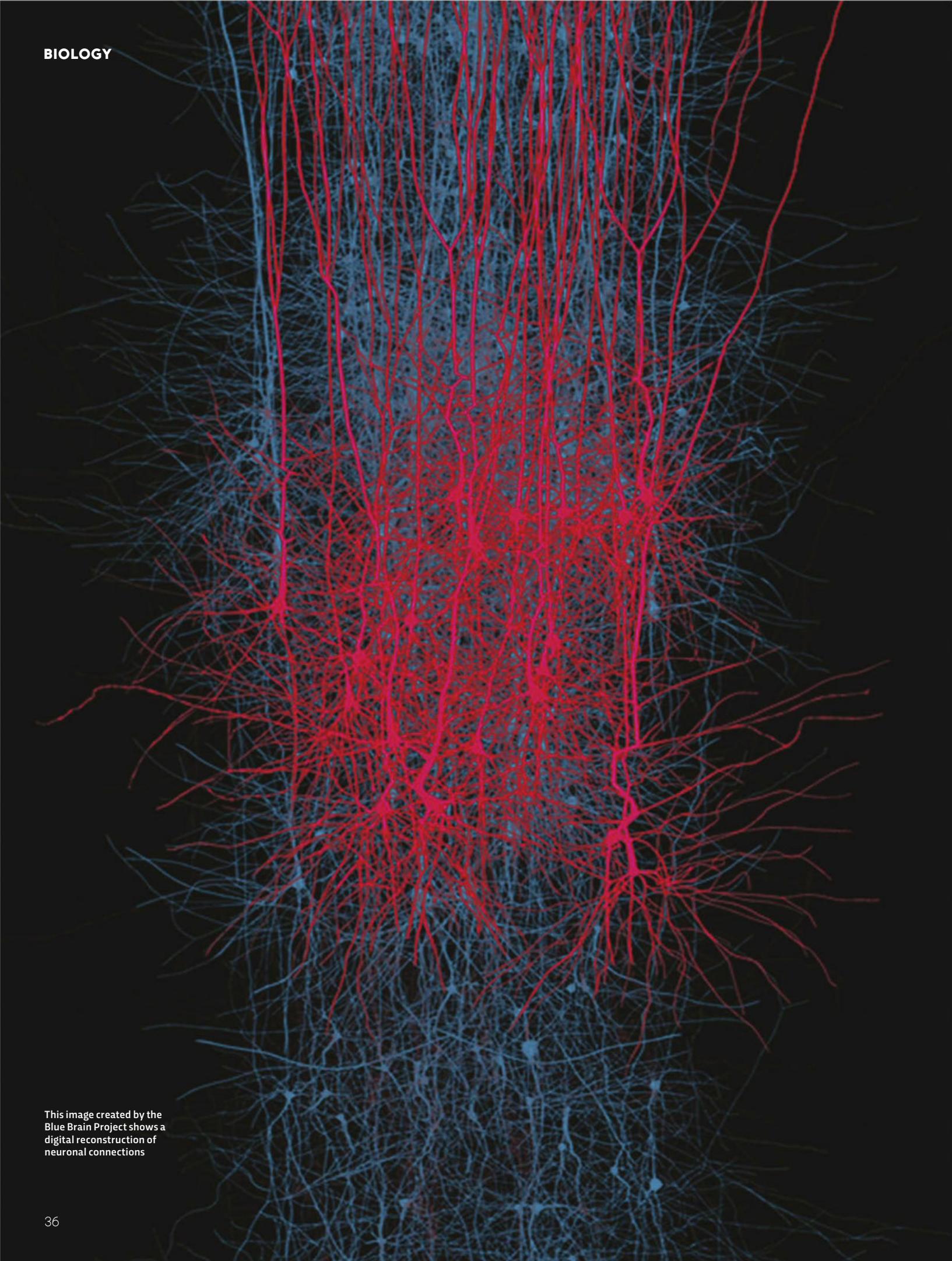
Two hundred years after Mary Shelley wrote *Frankenstein*, we look at how today's scientists can create life in the lab

Words: Duncan Geere



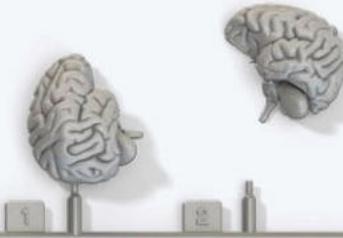
In June 1816, a monster was born. Mary Shelley (then Mary Godwin) was holidaying along the banks of Lake Geneva with Lord Byron and her lover, Percy Shelley. It was a cold, wet summer, so, stuck indoors, Byron challenged everyone in the group to write a ghost story. A few days later, Mary Shelley began working on what would become *Frankenstein*. Shelley's story was undoubtedly

influenced by the science of the day, but what would have inspired her if she were alive today? Regenerative medicine and biotechnology are advancing at a breakneck pace, and the idea of creating life in the lab is looking less and less implausible. Over the following pages, we look at the science that's making Mary Shelley's vision a reality 200 years on. ➤



This image created by the Blue Brain Project shows a digital reconstruction of neuronal connections

THE BRAIN & MIND



Teams around the world are racing to create the first working replica of a brain

One of the most ambitious projects hoping to replicate a mind is the Blue Brain Project – an attempt to reverse-engineer mammalian brain circuitry. To begin with, the team is building a biologically-realistic digital simulation of the neurons in a rat brain. “Although the rat brain is very different from the human brain, a lot of the basic biology is the same,” the team at the Blue Brain Project says. “Research strategies and tools we have developed in rats could also, in principle, be applied to humans.”

A breakthrough in this project came last October, when scientists completed a draft simulation of part of the rat neocortex, a region of the brain key to processing sensory information. They reconstructed a section of brain tissue about one-third of a cubic millimetre in volume, containing around 30,000 neurons connected by nearly 40 million synapses. The electrical activity of the virtual tissue closely mirrored activity seen in real brains. But the researchers admit that their work has only just begun. The

human brain contains around 86 billion neurons – nearly three million times the number achieved with the rat simulation.

Meanwhile, in the US, another brain-mapping scheme, the Human Connectome project, is making some interesting breakthroughs. Analysis of the connectomes – blueprints of the brain’s connections – of nearly 500 people found that those with more positive traits (such as better endurance and memory) tended to have more strongly connected brains. If we’re going to create a functioning being, knowledge of how the brain’s architecture links to physical and mental traits will be vital.

BUILD A BRAIN

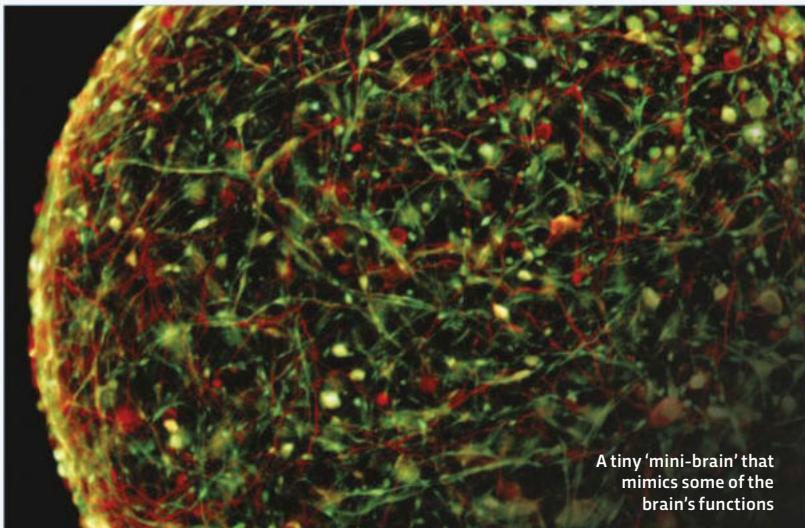
While some researchers try to model brains using bits and bytes, others are trying to build biological copies. Thomas Hartung of Johns Hopkins University recently exhibited balls of human brain cells the size of a foetus’s brain at two months old. According to Hartung, they show ‘spontaneous electrophysiological

activity’, meaning that they send electrical signals to each other without external stimulus. While they can’t grow any larger as they lack a blood supply, the mini-brains might be useful in drug testing as they will let researchers observe the effects of substances on neural activity without resorting to a living subject.

CREATE A CONSCIOUSNESS

Finally, Russian billionaire Dmitry Itskov is funding research into whether it’s possible to upload a human consciousness to a computer. His organisation, 2045 Initiative, aims to make people immortal with the help of neural interfaces and robotics. There are

“If scientists simulated a brain in a supercomputer, hopefully they’ll upload a personality that’s unlikely to turn against its creators”



some huge roadblocks to overcome, but it doesn’t seem to violate any physical laws. If scientists were to simulate a brain in a supercomputer, hopefully they’ll use this technology to upload a personality that’s unlikely to turn against its creator. Back in the present day, the closest we’ve come to building a working brain seems to be the OpenWorm project. After mapping the connectome of a nematode worm, scientists are now building digital equivalents of its muscles and organs, with the aim of bringing it to life in a virtual world. Look out, Dr Frankenstein. ☺



THE RE-ANIMATOR'S TOOLKIT

Want to be the next Dr Frankenstein? These essential terms should help you on your way...

BIOPRINTING

The process of creating body tissue using 3D printing technologies. Cells are gradually layered up in the shape and form required and then allowed to grow together before the scaffold holding them in place is removed.

BRAIN-COMPUTER INTERFACE

A direct communication pathway between a brain and an external device. Often used to research human cognitive and sensory functions, and in mind-controlled prosthetic limbs.

CONNECTOME

The map of neural connections in the brain and nervous system. Only one animal has had its entire connectome mapped – a tiny roundworm called *Caenorhabditis elegans*.

IMMUNOSUPPRESSANTS

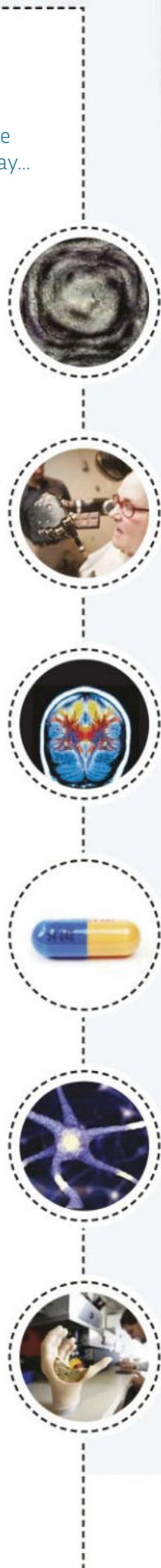
A cocktail of drugs that intentionally weakens the body's immune system, lowering the chance of rejection of a transplanted organ. They also leave the body more prone to infection.

NEURONS

Specialised cells that transmit information to other cells. The human brain and nervous system contain about 100 billion of them, sending electrical impulses to where they're needed.

PROSTHESIS

An artificial device that replaces a missing body part. Some modern versions feature robotic capabilities, and research is being conducted into bestowing them with a sense of touch.



*Could we ever transplant a head?
One man thinks so...*

► The hardest part of building a creature from scratch, after the brain, is the head and face. While head transplant experiments have been carried out on animals for more than a century, all attempts have ended in paralysis and the animal's death.

The most influential researcher in this area was scientist Vladimir Demikhov, who experimented with dog head transplants in the Soviet Union in the 1950s. He was unsuccessful, but his other experiments in transplanting



"The surgeon's plan involves slicing off the patient's head using a clean, fast procedure"

organs between animals significantly advanced the field – including the use of immunosuppressants to reduce the risk of a body rejecting the transplanted organ. His work led directly to the first human heart transplant in 1967.

SWAP SOME HEADS

In 1970, a team of researchers led by US neurosurgeon Robert J White attempted to transplant the head of a monkey onto the body of another. The procedure was a partial success, with the animal surviving for some time after the operation and reportedly able to sense the world around it, but the public greeted the news with



widespread disapproval.

More recently, a new figure has appeared on the scene. Sergio Canavero, an Italian neurosurgeon, has attracted widespread media attention over claims that he'll perform the first successful human head transplant in 2017, with some calling him the 'real-life Frankenstein'. Canavero already has a patient – a 30-year-old Russian named Valery Spiridonov with spinal muscular atrophy. The surgeon's plan involves slicing off Spiridonov's head using a clean, fast procedure, and then connecting it to the donor body's spinal cord with a polyethylene glycol 'glue'. But there is much doubt – not only over whether he'll succeed, but also whether he'll even be able to attempt it in the face of financial and ethical constraints. At the time of writing, Canavero is still seeking funds.

MAKE A FACE

If heads are too hard, then faces

are easier. In November 2015, Patrick Hardison, a firefighter who had been horribly burned in an accident, was given the face of a brain-dead man during a 26-hour-long operation at New York University's Langone Medical Center. The surgery came almost exactly 10 years after the first partial facial transplant in

2005 and was described as "a critically important contribution to the advancement of science and medicine" by the medical centre's dean Robert Grossman. Recipients of facial transplants must take immunosuppressant drugs for the rest of their lives, and are at greater risk of suffering from infections and cancer. ▶

ABOVE: Sergio Canavero is confident that he can perform a successful head transplant on a human patient

LEFT: Dr Eduardo Rodriguez performed the most extensive face transplant to date on patient Patrick Hardison (on screen)



THE BODY

From 3D-printed organs to artificial skin, here's how we'll build the body

Once the brain and head are constructed, the rest of the body is easier to build. Bones are probably the simplest of all – we've been fixing bones with pins, rods and screws since the middle of the 19th Century. Titanium is often used to create replacement bones because it's non-toxic and compatible with living tissue, leading to implants that can last more than 30 years.

"Human skin is surprisingly easy to print, thanks to its layered structure"

Frankenstein sourced his bones from 'charnel houses', but he would have loved 3D printers, which can form perfect replica bones. In 2012, one 83-year-old woman was given a 3D-printed lower jaw that took just a few hours to print and install. The patient was able to speak shortly after waking up from the anaesthetic, and could soon

RIGHT: Vital organs can now be built in the laboratory

BELOW: The layered structure of human skin makes it easy to recreate with 3D printing



swallow again. A similar titanium ribcage was installed in a Spanish patient in 2015.

Organs are a little harder, but we're getting there. Bioprinters have been able to create human tissue for a while. Last year, researchers from Carnegie Mellon University adapted an off-the-shelf MakerBot 3D printer to do the same. Artificial hearts, kidneys and livers have all been printed, usually by suspending living cells in a gel-like substance. The cells start to grow into tissue, and the gel is washed away to leave the organ behind.

STAYING ALIVE

The difficulty with 3D-printed tissue is keeping it alive, as this requires tiny blood vessels. In 2014, scientists in Australia and the US took the first steps towards integrating artificial blood vessels into tissue, and just a few months ago researchers at North Carolina's Wake Forest University published the details of a 3D printer that could create everything – organs, tissues and bones – that could all be implanted into humans. The field is moving fast, but most experts warn against optimism, saying it'll likely be decades before we see the tech becoming common.

That just leaves skin, which is surprisingly easy to print, thanks to its layered structure. In 2015, L'Oréal announced that it was teaming up with bioengineering start-up Organovo to 3D-print human skin. The companies said the skin would be used in product tests, though some medics have suggested it might have more value in burns units and trauma centres. ➤





REAL-LIFE RESURRECTIONS

Death isn't always the end. Many people have regained consciousness after being pronounced clinically dead

EXTREME TRIP

In 2001, the *Emergency Medicine Journal* described a British man who had overdosed on drugs. On the way to hospital, he went into cardiac arrest, and resuscitation attempts failed. He was declared dead, but then a pulse was detected. He recovered fully.

I'M NOT DEAD!

Eleanor Markham, a young American woman, was pronounced dead in 1894 by her family's physician. The weather was warm so a burial was hastily arranged for two days later, but on the way to the graveyard the hearse was halted by a banging inside the coffin.

SURPRISE REVIVAL

In 2014, Walter Williams, a 78-year-old man from the US, awoke in a body bag after being declared dead earlier the same day. It's thought that a defibrillator in his chest revived him. The next day, he was well enough to speak, but died 15 days later.

SHOCKING RECOVERY

Judith Johnson, a 61-year-old American woman, was declared dead in 2007 after being given medicines and shocks in an attempt to revive her. Later, she was discovered in the morgue to be alive and breathing. She sued the hospital and medical staff.

THE SPLASH OF 'LIFE'

The final challenge: how do we bring it all to life?

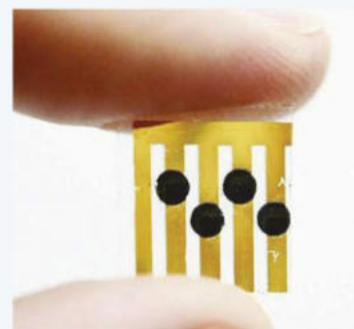
Now we're back to where we began – the 'spark' of life itself, something which we're not much closer to understanding today than during Mary Shelley's time. Dr Frankenstein famously discovered the secret of life: "I became myself capable of bestowing animation upon lifeless matter." But no real-world scientists have come close.

So animating our bundle of 3D-printed organs, transplanted head and digital brain is no easy task. Life is infinitely more complicated than a chemical reaction, or software algorithm – that's why we can only approximate it in the lab, not replicate it entirely.

But let's say we could wave a magic wand to create that vital spark. How would it interact with the body we've created for it?

Mind-controlled prostheses are

already a reality – researchers at Johns Hopkins University recently announced a prosthetic arm whose individual fingers can be controlled by the brain. To configure it, electrodes were implanted over the part of the brain that controls hand and arm movements, with researchers tracking the locations that emitted an electric pulse when the subject moved their fingers.



An artificial 'nose' created by C2Sense



THE TALE OF THE REANIMATED CORPSE

This grisly experiment may have inspired Mary Shelley's masterpiece

When Londoner George Forster was convicted of murder in 1803, the judge handed down a sentence that would sound rather unusual today. It called not only for his death by hanging, but for dissection afterwards – a common practice at

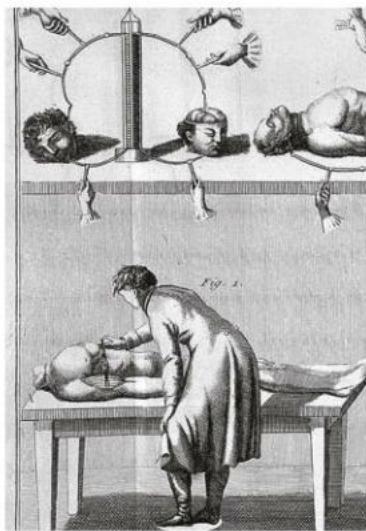
the time, to provide the medical world with corpses to experiment on and also to prevent the condemned from rising again on Judgment Day.

After being hanged on the morning of 18 January, Forster's body was carted down the street to a house where Giovanni Aldini, an Italian scientist, was waiting. Aldini wanted to show that corpses contained an 'animal electricity', and to do so he was going to apply a method named 'galvanism', after his uncle Luigi Galvani who'd discovered it previously.

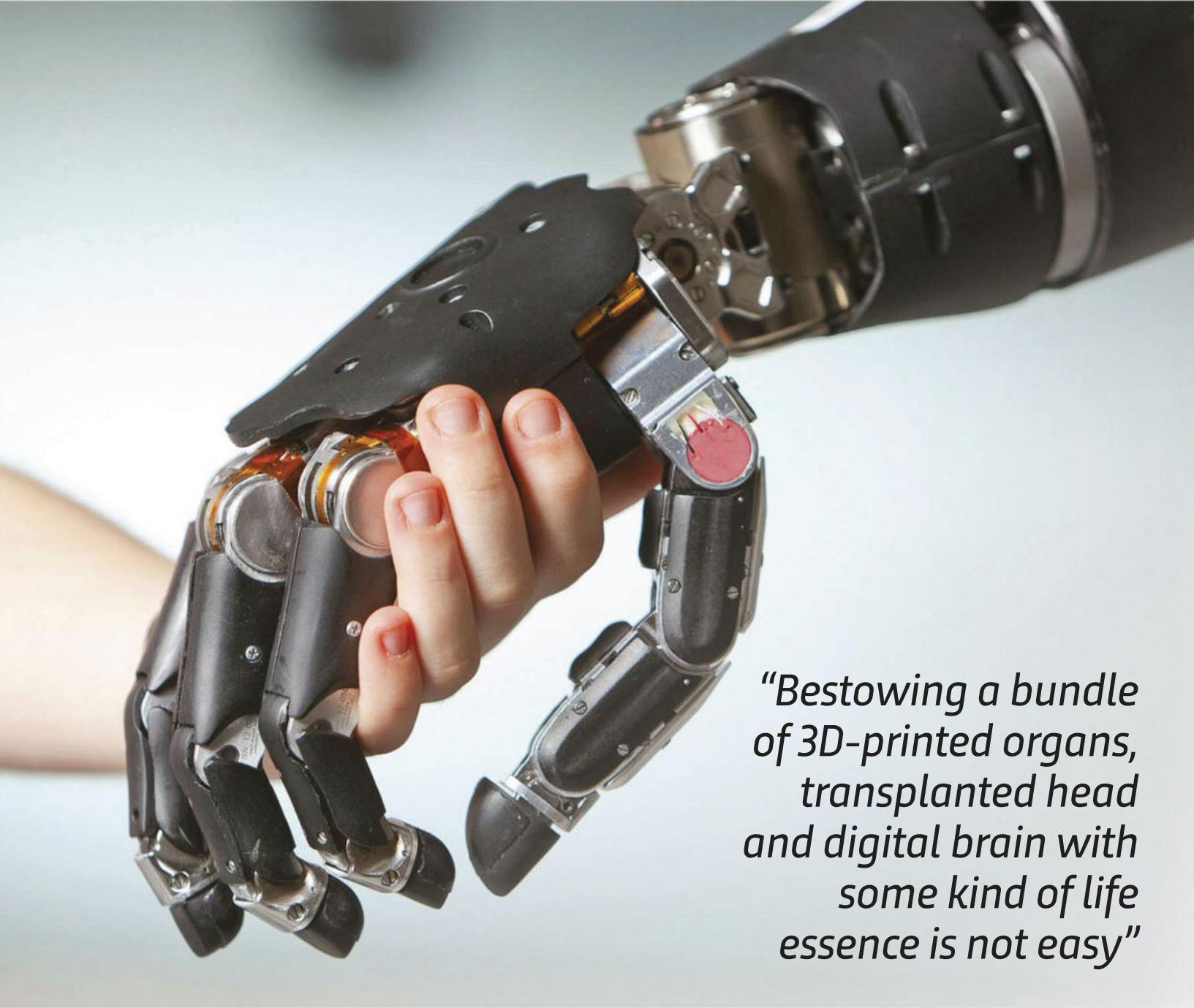
Aldini inserted a metal rod into Forster's mouth, and another into his ear. "On the first application of the process to the face, the jaws of the deceased criminal began to

quiver, and the adjoining muscles were horribly contorted, and one eye was actually opened," reported *The Newgate Calendar* at the time. "In the subsequent part of the process the right hand was raised and clenched, and the legs and thighs were set in motion."

The assembled crowd was shocked – so much so that the man who'd arranged for the delivery of the corpse died shortly after leaving. It became the most famous demonstration of galvanism, cited by author Mary Shelley (who was only five years old at the time of the experiment) as one of the evening discussion topics before she experienced the 'waking dream' that inspired the story of *Frankenstein*.



Galvanism experiments by Giovanni Aldini



"Bestowing a bundle of 3D-printed organs, transplanted head and digital brain with some kind of life essence is not easy"

These signals could then be used to trigger movements in the prosthetic hand in the same way.

SIMULATE SENSES

Currently, there are prosthetics that can deliver the sensation of touch. In 2013, University of California biologists connected up the brains of monkeys to an artificial fingertip equipped with sensors, using a similar brain-location-mapping process. They found that the monkeys responded the same way to 'feeling' in the artificial finger as in their real fingers. Human trials are still some way off, but the research holds promise for

amputees as well as those with spinal injuries.

Fredrik Winquist at Linköping University in Sweden has built an electronic tongue that can differentiate between tastes, while Massachusetts-based firm C2Sense has created a similar device for smell. Combined with cameras and microphones for sight and sound respectively, that's pretty much all the body's major senses covered.

Much work remains to be done, not least teaching a digital brain how to cope with these inputs and process them into actions. It's easy for us to quickly withdraw our hand when it touches a hot

ABOVE: A prosthetic arm and hand designed by Johns Hopkins University is just as dexterous as its 'real' counterpart

surface, but harder for a computer to perform all the calculations at a speed that avoids damage, while also processing continuous input from the rest of its body. A fully-functioning artificial being might be some way off yet, but it's surely only a matter of time. **F**

Duncan Geere is a freelance science and technology writer who is based in Gothenburg, Sweden.

DISCOVER MORE

- To read a BBC Future article about prosthetic limbs, visit bbc.in/1RF Dadc
- Listen to a BBC Radio 4 programme about the genesis of *Frankenstein* at bbc.in/1puCQwl

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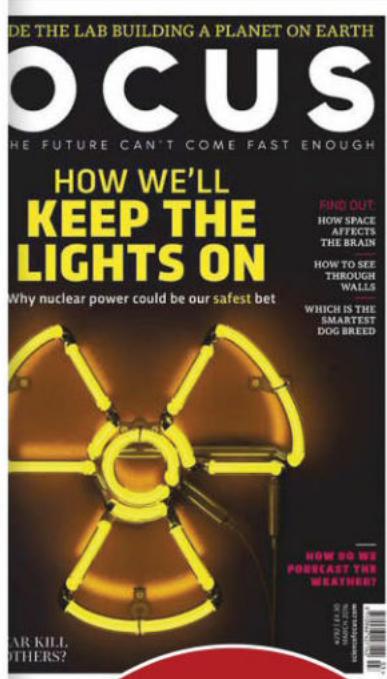
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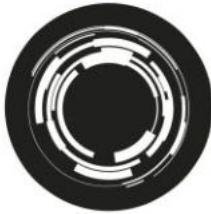
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SPACE





HOW WE'LL CAPTURE A BLACK HOLE

Next year, an Earth-sized telescope will attempt to photograph a black hole for the first time, and its images could make or break the laws of physics as we know them

Words: Colin Stuart

A radio dish swivels above vast plains of Antarctic ice, while another scans the skies almost 5,000 metres above sea level in the Chilean desert. Meanwhile, cosmic signals are pinging into receivers in California, Arizona, Hawaii, Mexico and Spain. Despite the distances between them, these radio dishes all form part of the same audacious project: a telescope the size of the Earth itself. This is the Event Horizon Telescope (EHT) and by this time next year, we'll have used it to see into the heart of a black hole. ➤

THE ANATOMY OF A **BLACK HOLE**



● Ordinary black holes are gargantuan relics formed by the deaths of the largest stars, those with masses tens of times that of the Sun. Even more brutal versions, with masses running into the equivalent of millions of stars, lurk deep in the heart of galaxies like our Milky Way. But while their masses are mighty, they are also the most compact objects in the cosmos. This extreme density leads to an incredibly fierce gravitational pull, one that twists and contorts the fabric of space around it. At a certain point – the event horizon – the black hole's power is so strong that even a beam of light is helpless to resist the relentless pull of gravity. The curvature of space is so extreme here that all escape routes simply lead straight back into the black hole. "They are

the most terrifying objects in the Universe," says Shep Doeleman, a member of the EHT team based at MIT's Haystack Observatory.

BREAKING GENERAL RELATIVITY

Our best picture of the environment around the event horizon of a black hole is laid out by Einstein's General Relativity. His equations, formulated over 100 years ago, describe how mass warps the fabric of space around it. However, many physicists suspect that in the strongest gravity fields its descriptive power might wane. "The event horizon of a black hole is the one place in the Universe where General Relativity might break down," says Doeleman. Finding a chink in its armour would be a real boon for physicists,

PHOTOS: GETTY, ESO

ALMA will soon be linked up to the Event Horizon Telescope. ALMA is located at an altitude of 5,000m in the Atacama Desert because the high and arid environment is essential to the function of the equipment

who have long sought a happy marriage between General Relativity and quantum theory. If General Relativity could be shown to be flawed, it might provide an insight into a deeper, more fundamental theory of the Universe.

So far, General Relativity has passed every test with flying colours, including the recent discovery of gravitational waves from colliding black holes. But we've only ever probed it in relatively weak gravitational fields. According to Prof Dimitrios Psaltis, a theoretical physicist at the University of Arizona, the tidal forces associated with galactic black holes are up to 100 million times stronger than those linked to the colliding black holes detected by the LIGO consortium in September last year. That makes supermassive black holes a natural laboratory for experimenting with Einstein's ideas.

The key will be looking at the black hole's 'shadow'. "Because of the strong gravity of the black hole, you wind up seeing a ring of light around it," says Doeleman. This ring is formed by light that is initially moving away from you but is bent back around towards you by the black hole. The shadow is the dark area inside the ring. Einstein's equations predict it should be roughly circular. Any significant deviation from a circular shadow would violate General Relativity.

Far and away the best black hole for this test is Sgr A* – the monster at the Milky Way's centre. Astronomers have been peering into the centre of the Galaxy since the mid-1990s, charting the passage of stars as they appear to orbit around something invisible. From the way these stars move, we know the black hole must tip the scales at about four million solar masses (one solar mass

"We need a resolution 2,000 times greater than that of the Hubble Space Telescope"

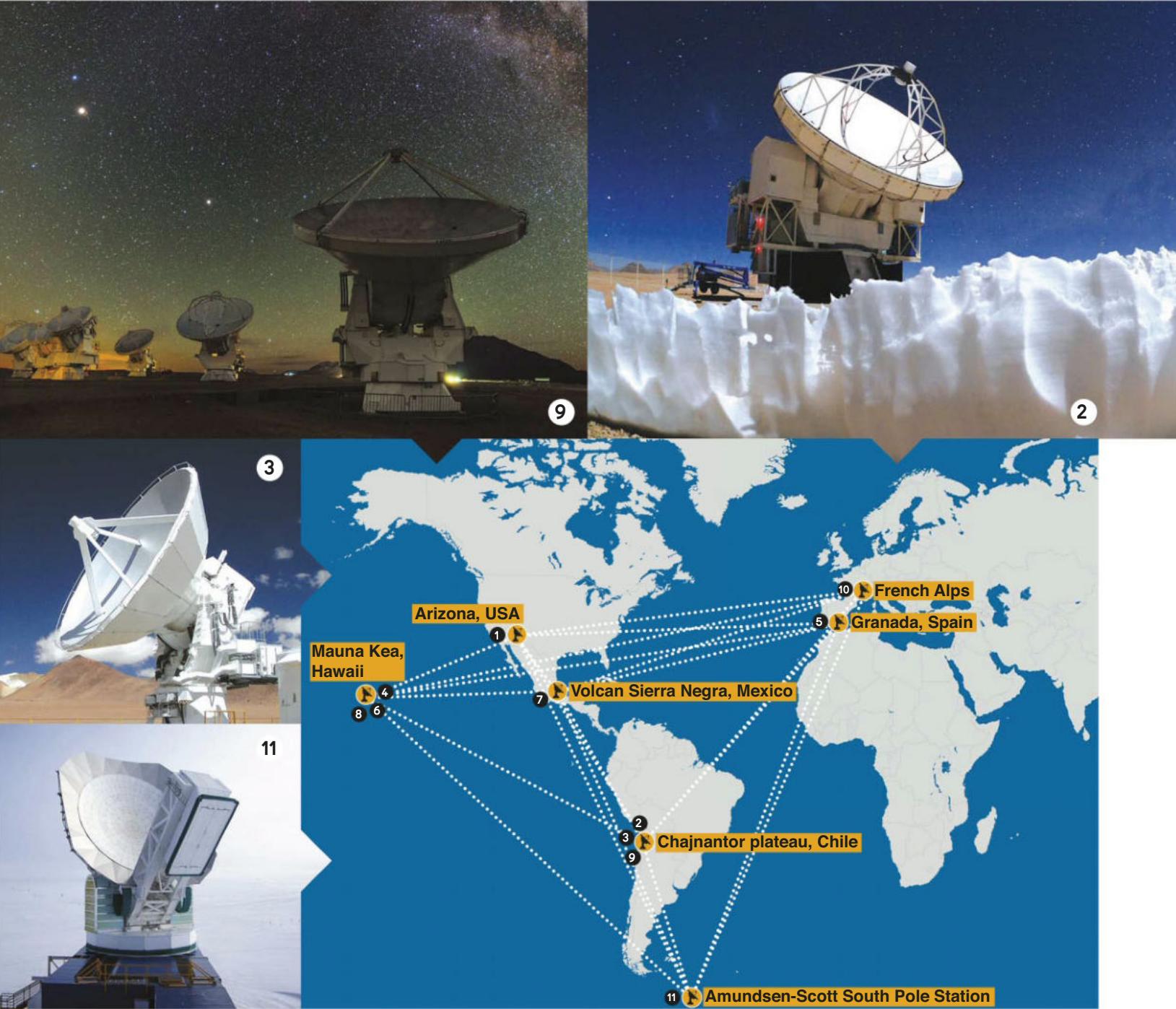
is equivalent to the mass of the Sun). Yet, for these stars to remain in stable orbits, its event horizon must be relatively small. "It's about a third of the orbit of Mercury," says Doeleman.

RESOLUTION SOLUTION

Testing the shape of Sgr A*'s shadow is only possible if we can see what's going on around its event horizon. But that's easier said than done. Not only is the event horizon physically small, it is also 26,000 light-years away, making it really tricky to hone in on. Of course, the smaller an object appears in the sky, the greater resolution your telescope requires in order to see it.

"We need a resolution 2,000 times greater than that of the Hubble Space Telescope," says Doeleman. That's the equivalent of being able to resolve a grapefruit on the Moon. As a general rule, the bigger the diameter of your 'scope, the higher its resolution. Hence the enormous separation needed between the EHT's component dishes. Using a technique known as Very Long





EVENT HORIZON TELESCOPE

*To photograph a black hole, scientists will need an Earth-sized telescope.
This means they will need to call in data from telescopes all around the planet*

TELESCOPE

- ① Arizona Radio Observatory Submillimeter Telescope
- ② Atacama Pathfinder Experiment (APEX)
- ③ Atacama Submillimeter Telescope Experiment (ASTE)
- ④ Caltech Submillimeter Observatory (CSO)
- ⑤ Institut de Radioastronomie Observatoire (IRAM)
- ⑥ James Clerk Maxwell Telescope (JCMT)
- ⑦ The Large Millimeter Telescope (LMT)
- ⑧ The Submillimeter Array (SMA)
- ⑨ Atacama Large Millimeter Array (ALMA)
- ⑩ Plateau de Bure Interferometer
- ⑪ South Pole Telescope

LOCATION

- Arizona
- Chajnantor plateau, Chile
- Chajnantor plateau, Chile
- Mauna Kea, Hawaii
- Granada, Spain
- Mauna Kea, Hawaii
- Volcan Sierra Negra, Mexico
- Mauna Kea, Hawaii
- Chajnantor plateau, Chile
- French Alps
- Amundsen-Scott South Pole Station

TELESCOPE TYPE

- Microwave
- Infrared and radio
- Microwave
- Microwave
- Radio
- Far IR, microwave
- Radio
- Radio
- Radio
- Radio
- Microwave, radio



● Baseline Interferometry (VLBI), astronomers can combine the radio signals arriving at dishes on four continents and get the same view as if they had a single dish the size of their total separation – a planet-sized telescope.

The logistics behind such a task are extreme. In order to join up the signals received by these far-flung dishes, the team is using accurate atomic clocks to note their precise arrival times at the different telescopes. The volume of information required means that 64GB of data, an iPad's worth, is recorded for every second of observation. Hundreds of terabytes of data are stored on memory drives in a single session and these are then flown to a central facility at MIT where only then are they synced up to provide a picture of a celestial object.

SNAPPING SPACE

Despite the many challenges, the project is well underway, with many telescopes already linked up. The first observations were made back in 2006, and subsequent explorations have been made of Sgr A*. However, the current EHT resolution isn't quite up to peering directly at the event horizon. But that is about to change. The EHT will soon welcome an impressive new partner to its ranks – the Atacama Large Millimeter/submillimeter Array (ALMA) in Chile. "In one stroke that will increase our sensitivity by a factor of 10," says Doeleman.

ALMA is a huge bank of radio dishes that work together as one. Researchers have already tested out a way to add 30 of ALMA's receivers to the EHT. In April, they flew to various EHT sites to further test ALMA's addition to the system. "The idea is to get it ready for full-on observations in the spring of 2017," Doeleman says.

So we're potentially just a year away from the event horizon of a black hole sharpening into view for the first time. And that will do more

GALAXY M87 IN FOCUS

- Discovered by French astronomer Charles Messier in 1781
- Located 53.5 million light-years from Earth in the constellation of Virgo in the centre of the Milky Way
- Galaxy estimated to weigh around 2.7 trillion solar masses
- Measures 120,000 light-years across



SGR A* BLACK HOLE IN FOCUS

- Discovered by astronomer Karl Jansky in February 1974 when he detected radio waves coming from the centre of the Milky Way
- Located 26,000 light-years from Earth in the constellation of Sagittarius
- Thought to weigh about four million solar masses
- Measures 44 million km across



than simply test General Relativity. The four million solar mass supermassive black hole at the centre of the Milky Way may seem large, but it pales in comparison to the seven billion solar mass leviathan lurking at the centre of the galaxy M87. M87 is an elliptical galaxy, and its most striking feature is a vast jet that erupts 5,000 light-years away from its centre. Previous observations with the EHT have looked deep into the base of the M87 jet, but exactly what causes it isn't clear. It's believed to be related to matter falling towards the black hole and interacting with strong magnetic fields, but getting a view nearer to the event horizon is key.

"We want to know how matter gets loaded onto the magnetic field lines and gets ejected," explains Psaltis. "These are things we currently have to infer, but future observations with the EHT will be the first time we'll be able to do it snapshot by snapshot."

Observing how matter gathers around black holes, a process known as accretion, could also give us an insight into why the Milky Way's central black hole seems to be on what Doeleman calls a 'starvation diet'. Only 1 per cent of the surrounding material is thought to make it to the event horizon. As this matter spirals in, it becomes superheated and gives off X-ray radiation. So, if Sgr A* had a more substantial appetite, it is likely the Milky Way would be flooded with a lot more high-energy radiation. That fact that it isn't might help explain why biology has been able to thrive within it. So not only will next year's EHT observations provide the sternest test yet of General Relativity, they might begin to tell us why we're even here to test it. 

Colin Stuart (@skyponderer) is an astronomy writer and author of *The Big Questions In Science*.

DISCOVER MORE

 Listen to Prof Stephen Hawking's two Reith Lectures on BBC Radio 4 about the nature of black holes at bit.ly/Reith_Lecture

Ismail has never seen his mother's face.

A MILLION MIRACLES



Will you send a gift and make a blind child see?

Baby Ismail was born with cataracts in both eyes. Following his mother's voice was his only way to navigate the world and his future looked bleak. By sending a gift today, you can give sight to a blind child like him.

Having been born blind, Ismail urgently needed an operation – because the longer a child is blind, the harder it becomes to restore their sight until, eventually, they are left in permanent darkness.

Ismail's miracle moment

Thankfully, eight-month-old Ismail got the cataract surgery he needed. As his bandages were removed, he beamed at his mother in wonder and amazement, clearly delighted to see her face, and the world, for the very first time. It was a miracle moment – and one you can give to another blind child today.



Ismail was amazed and delighted to see his big brother, Ibrahim, for the first time ever. A gift of £120 from you today could make a miracle moment like this happen for another blind child.

“Cataract surgery is one of the most cost-effective health interventions.”

World Health Organization

This is your chance to make a blind child see

While it's wonderful that Ismail got his sight back, there are 200,000 more children like him, who are waiting for cataract surgery and running out of time.

Their suffering is needless. You can give sight to a blind child by funding the miracle operation to replace their clouded lenses with clear ones. Best of all, the change you make in that child's life will last forever.

Making A Million Miracles happen

Cataract is the leading cause of preventable blindness and demand for miracle sight-restoring operations is increasing. That's why Sightsavers has committed to this ambitious project – to carry out A Million Miracles by 2018.

Are you ready to meet your miracle?

To say thank you, we'll email you a picture of a child like Ismail whose sight has been restored through cataract surgery. It can't fail to inspire you – witnessing a child's utter joy as they see the world for the very first time and knowing you've changed their life forever.



Surgery + Anaesthetic + Aftercare = £120 child cataract surgery

Because children's eyes are still growing and developing, it's more complicated and more expensive to restore a child's sight than an adult's. Children need surgery as early as possible – and they need a general anaesthetic and more aftercare as they grow. All of this costs £120, but the result is priceless – a blind child seeing for the first time.

Please send your gift today

Your help can't come soon enough for a child like Ismail, who is waiting for a miracle sight-restoring operation. Please send your gift now and give another child the chance to open their eyes and see the world for the first time.

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ROBIN INCE ON... NANOMEDICINES

"USING NANOPARTICLES AND NOT SUBMARINES AVOIDS THE RISK OF ANY MINIATURISED VILLAINS"

That means that our whole Solar System could be, like, one tiny atom in the fingernail of some other giant being.

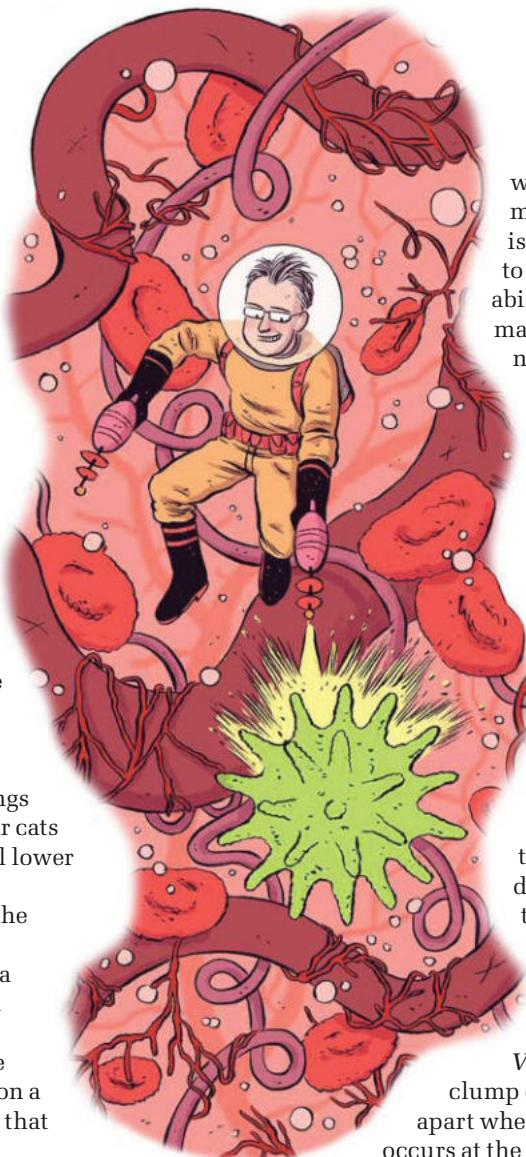
This is too much! That means one tiny atom in my fingernail could be..."

"Could be one little tiny universe."

In days gone by, this was the stereotypical stoned human conversation, as immortalised by *National Lampoon's Animal House*. As drugs have changed and our understanding of physics has advanced, I imagine the conversations have moved on to discussions of the possibility that we are all some sort of simulation inside a simulation inside a simulation, or some other bubble inspired by *The Matrix*. Evidence for populations of sentient beings thriving on electrons – even small, clever cats bouncing in and out of existence – is still lower than scant.

Go up a few orders of magnitude, and the candlelit hours can be spent pondering something that's delightfully true: what a walking zoo we are. As Ed Yong states in the Walt Whitman-inspired title of his upcoming book *I Contain Multitudes*, we are never alone. Yong elegantly takes us on a tour of the colonies of bacteria and fungi that make up our microbiome – the teeming savannah of our skin surface and the oceans of life that swim within, as well as the "unfathomable numbers" of viruses that make up our "virome". There is a psychosomatic itchiness that kicks in when you ponder this diverse population. There are new worlds to conquer, and some are within us.

And with this, I see images of Raquel Welch and Donald Pleasence in Richard Fleischer's *Fantastic Voyage*. This 1966 sci-fi film imagined a world where doctors and a submarine could be miniaturised and injected into the sick to combat life-threatening illnesses. Like much imaginative fiction, it is both a



way off, and far closer to reality than you may think. From my investigations, there is little evidence of research grants going to the manufacture of shrink rays, but our ability to target sickness at a tiny scale is making remarkable headway via nanomedicine.

I recently introduced Prof Donald Ingber of the Wyss Institute at a public outreach lecture at Queen Mary University of London. This was a fiesta of nanomedicine. I am glad I never had corrective laser surgery, because on that particular day my glasses kept my eyes from flying out of my head as I heard about the remarkable possibilities that blossom from the human imagination.

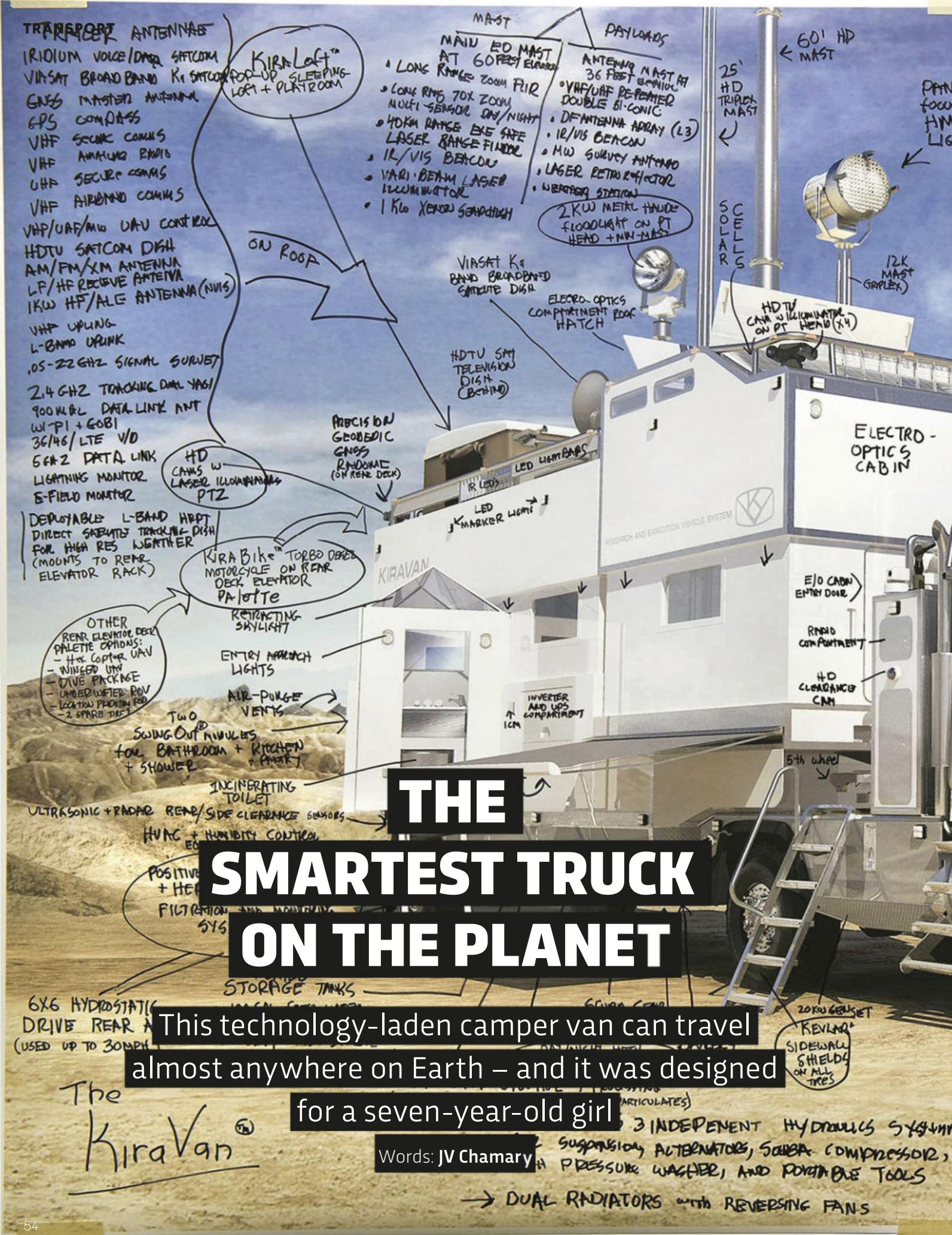
There are chips that can replicate human organs so exactly that when we test drugs on them rather than animals, we can expect much more illuminating and useful results. Then there are nanotechnologies that ferry drugs directly to tumours. Meanwhile, the battle against sepsis is fought with tiny magnetic nanobeads that pull toxins from patients.

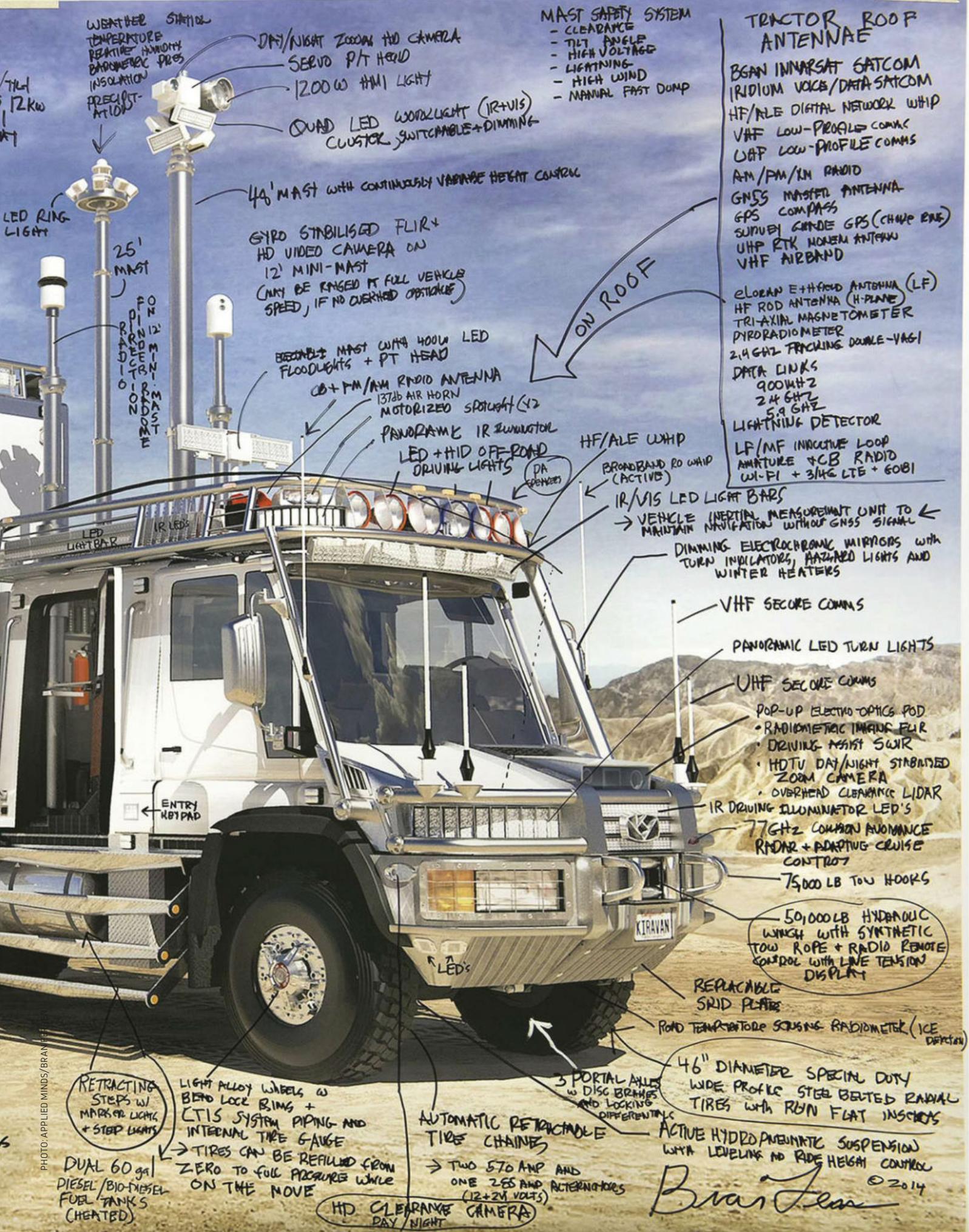
But what of blood clots, the enemy that had to be destroyed in *Fantastic Voyage*? Today's Proteus submarine is a clump of nanoparticles that will only break apart when subjected to stress – something that occurs at the site of a vascular blockage. As they break apart, they disperse the blood clot. Using nanoparticles rather than submarines also avoids the problem of villainous, miniaturised scientists intent on jeopardising the mission. Richard Fleischer's other science fiction movie was *Soylent Green*, in which people survive on plankton – hopefully this isn't inspiring as much research.

Robin Ince is a comedian and writer who presents, with Prof Brian Cox, the BBC Radio 4 series *The Infinite Monkey Cage*.

NEXT ISSUE: MUSIC FESTIVALS

When I was young, I wanted to be a zookeeper. Perhaps the best way to do that now is to move into nanomedicine and tend the animals I keep with me.





A HIGH-TECH HOME FROM HOME

Detailing the technology and design that makes KiraVan such a unique vehicle

NAVIGATION

Receivers for global navigation satellite systems keep track of the KiraVan. But if satellite signals aren't detected, fibre-optic gyroscopes and precise accelerometers record the truck's position, direction and velocity to continue mapping its location.

TRAILER

The trailer shares power and other systems while attached to the tractor, but can also operate as an independent base station. It's made from composite materials such as aramid and fibreglass, and its walls offer radio-frequency shielding and lightning protection. The main sleeping loft is on a balcony, below a pop-up 'penthouse' tent. The kitchen and bathroom areas are expandable, increasing the internal volume by 50 per cent.

COMPUTERS

There is an office space with two networked computers, Wi-Fi for portable devices and access to the KiraVan's computer systems. A 4K monitor can act as a graphics terminal to view maps or edit video, while a media library and satellite TV offer entertainment.

SENSORS

Telescopic masts with pneumatic servos control the height of external sensors, which include long-range optics such as infrared and night-vision cameras. The tallest mast can raise those electro-optical systems to 17m above ground level.

COMMUNICATIONS

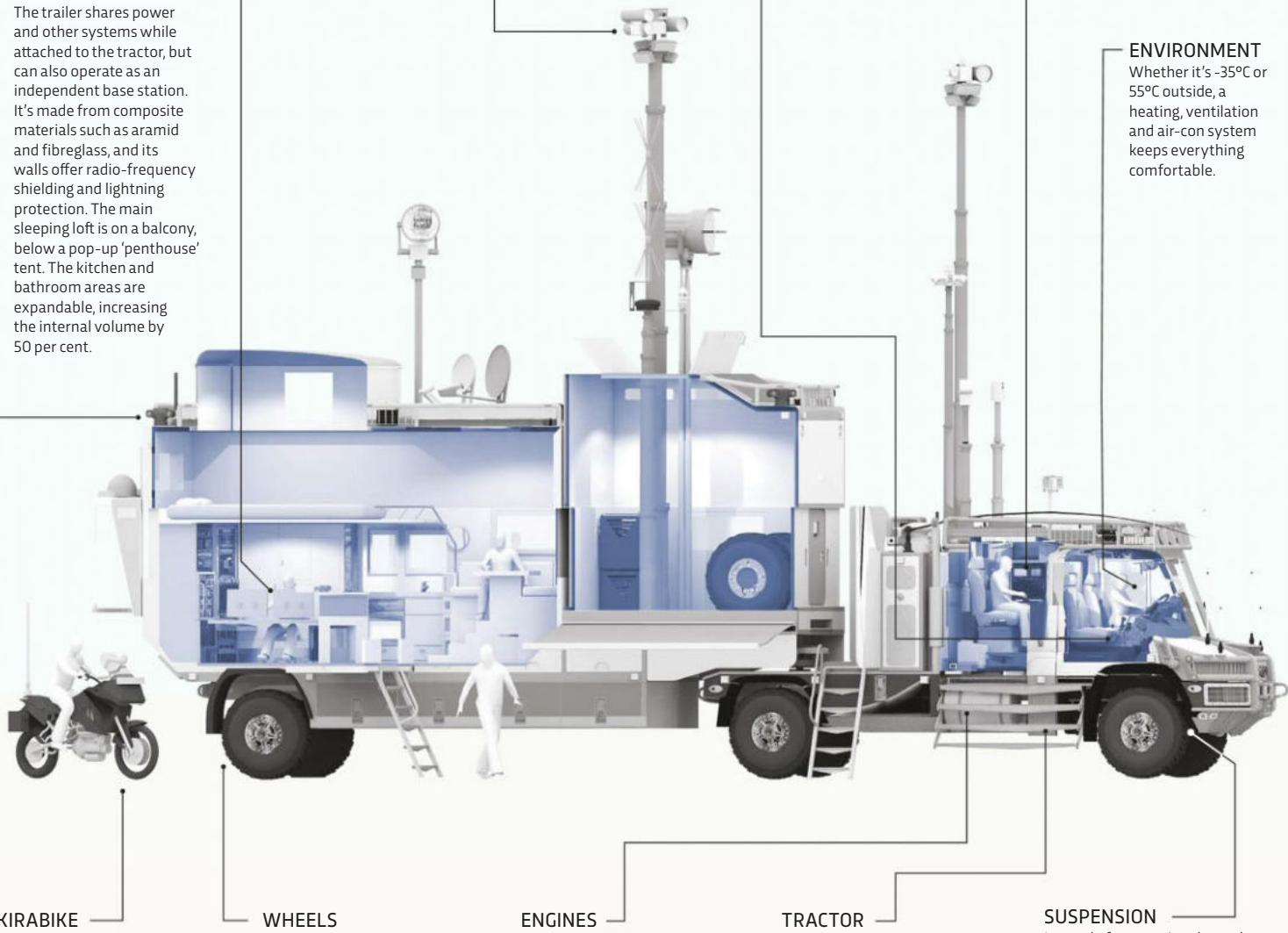
Satellite communication provides wireless broadband at up to 10Mbps download and 5Mbps upload speeds, working in most areas globally. When satcom services aren't available, the KiraVan uses an antenna for line-of-sight propagation via VHF or UHF radio signals.

COCKPIT

Glass cockpits developed for aircraft can now be found in land vehicles such as the Tesla Model S. The KiraVan's cockpit system is far more sophisticated than a passenger dashboard, with control and instrument panels across no fewer than 11 displays, including six touchscreens.

ENVIRONMENT

Whether it's -35°C or 55°C outside, a heating, ventilation and air-con system keeps everything comfortable.



KIRABIKE

The Kirabike is mounted on an elevator at the trailer's rear. This motorcycle serves as a 'dinghy' for short trips such as grocery shopping, and features a turbo-diesel engine with 100mpg fuel economy. It can use VHF and UHF radio for communication and includes a rugged tablet for internet access.

WHEELS

Each Kevlar-reinforced Michelin tyre is 116cm (46in) wide and weighs 135kg. Strong yet light alloy rims allow the wheels to run flat, while a self-inflation system can refill tyres in under five minutes. Tyre chains can be deployed for traction on slippery surfaces like ice, even while the vehicle is in motion.

ENGINES

A six-cylinder, 260bhp turbo-diesel engine powers the tractor, while 650-litre tanks supply it with enough fuel for a 3,200km driving range. In the trailer, a quiet 25kW diesel generator transfers mechanical energy to five alternators to create electric current, helped by a solar battery charging system.

TRACTOR

The tractor is a Mercedes-Benz 'UniMog' truck with a stretched and strengthened chassis. Four-wheel drive provides off-road power and a top speed of 112km/h (70mph) while on the road. A hydrostatic system can transfer power to the rear axle for six-wheel drive up to 40km/h (25mph).

SUSPENSION

Instead of conventional metal springs or shock absorbers, the KiraVan uses a nitrogen-over-oil system controlled by the truck's computers. As in many off-road vehicles, the suspension is attached to portal axles (the tube is above the centre of the wheel hub) for high ground clearance and added torque.



A

touchscreen cockpit, fibre-optic gyroscopes, night vision cameras... the KiraVan Expedition

System has it all. This super-smart truck is also the ultimate all-terrain vehicle: a 4x4 that can handle sand or snow, climb hills, cross streams and explore the world's most remote regions. Built for endurance over long distances, the truck can carry enough supplies to sustain a three-person crew for three weeks. If satellite communication isn't available, it can navigate via high-frequency radio signals. A 700-litre tank can be topped up with water passed through a silver-lined antimicrobial, ultraviolet filtration system, while salt water is first desalinated by reverse-osmosis.

The high-tech van is the brainchild of inventor Bran Ferren, who named it after his daughter, Kira. In 2010, Ferren finished converting a Mercedes-Benz UniMog truck into a 'MaxiMog' with extras like cameras and videoconferencing. His daughter was born while he was planning the MaxiMog's successor, which Ferren says inspired him to design a more child-friendly vehicle. ☀



TOP: The KiraVan can happily traverse just about any terrain our planet can throw at it

ABOVE: The operator's console houses communications equipment, with a joystick and display for operating RC vehicles

LEFT: The galley has all the appliances you need to cook in the wild, and was designed with input from a chef – Kira's mother



“Upon Kira’s arrival,” he says, “the notion was, well, something that’s better suited to a family would be appropriate.”

Everything is packed into a modified tractor and trailer that’s 16m long and weighs up to 23.5 tonnes (limited to 19 tonnes off-road). It has areas for Kira to work and play, including a ‘penthouse’ in the trailer. Ferren’s daughter is closely involved in the van’s design and “constantly has input”, but the KiraVan isn’t just for family outings. It can be used for all sorts of expeditions for a variety of purposes, from geology and archaeology to filmmaking. Sensors mounted on telescopic masts can search for dig sites, for example, or capture images for a

high-resolution gigabit panorama.

“It’s designed to support a very flexible range of activities,” says Ferren, who believes in testing tech himself. “If you’re going to actually design, engineer and build things, you need to have your own first-hand experience with them.”

Ferren certainly has the experience. After producing special effects for Hollywood, which earned him an Oscar nomination, he became head of Walt Disney Imagineering, the R&D department that builds theme park rides. He is now co-founder and chief creative officer of Applied Minds, an R&D firm based in Burbank, California.

APPLIED TECHNOLOGY

Ferren’s vision for KiraVan is

implemented by a team of 30-40 employees, which can rise to 100 when specific skills (such as welding) are needed to bring hardware together. Anticipating that certain things, such as computer software, will no longer be state-of-the-art by the time Kira is old enough to drive, Ferren has made the van modular so it’s easy to upgrade. If a component is likely to go obsolete sooner rather than later, it’s designed in such a way that it’s straightforward to swap out.

Applied Minds is also using the KiraVan as a platform for research projects. Testing technologies might mean adapting sports car parts or creating something new. “The vast majority of the time, standard technology won’t do,” Ferren



PHOTOS: APPLIED MINDS/BRAN FERREN X3; JAMES DUNCAN DAVIDSON/TED

explains. "There are dozens and dozens of unique things on the vehicle, and each of them presented a creative, technical and often aesthetic challenge."

One such challenge is balancing on-road and off-road performance, as there's a trade-off between driving on highways, when a low centre of gravity helps, and handling rocky terrain, which requires high ground clearance. Ferren also points out that, like all modes of transport, the van needs to cope with turbulence. "It's more complicated designing



LEFT: In the cockpit, switches and screens over the windscreen control external sensors and lights, while the central console is for driving

ABOVE: This is Bran Ferren's sleeping area. The ladder leads to his daughter's bedroom above

RIGHT: The KiraVan has many attributes and abilities. Stealth, though, isn't really one of them

BELOW: Bran Ferren developed the vehicle for his young daughter



a vehicle like this than a plane or a boat," he says.

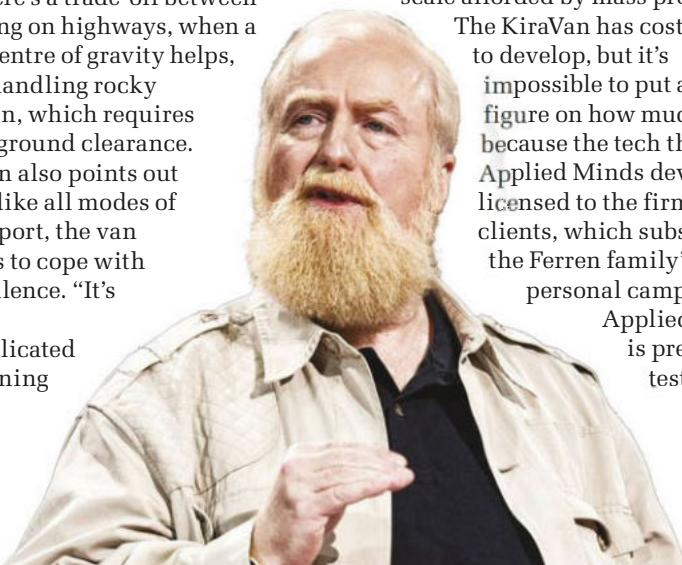
Ferren compares his creation to another luxury vehicle: a yacht. Both are custom creations that are expensive to make because they can't benefit from the economies of scale afforded by mass production.

The KiraVan has cost millions to develop, but it's impossible to put an exact figure on how much, partly because the tech that Applied Minds develops is licensed to the firm's clients, which subsidises the Ferren family's

personal camper van. Applied Minds is preparing to test the

KiraVan in the extreme heat of Death Valley this summer, and Ferren estimates that the truck is 80 per cent complete and should be ready to roll in about a year's time. So once it's finished, where does Kira want to explore first?

"It's not like she wakes up in the morning and says, 'We need to go to the Grand Canyon!'" says Ferren. But he adds that his own parents were artists with wanderlust. "That desire to travel and see the world and experience other cultures definitely transferred to me, and hopefully it will to her as well." ■



JV Chamary is a freelance science and technology writer based in Bristol.

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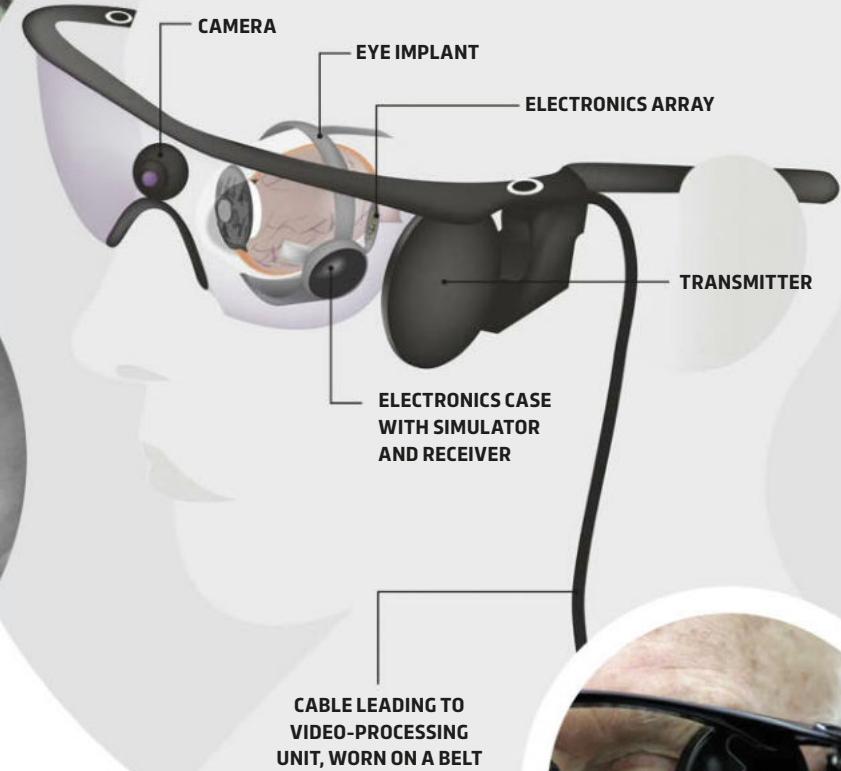
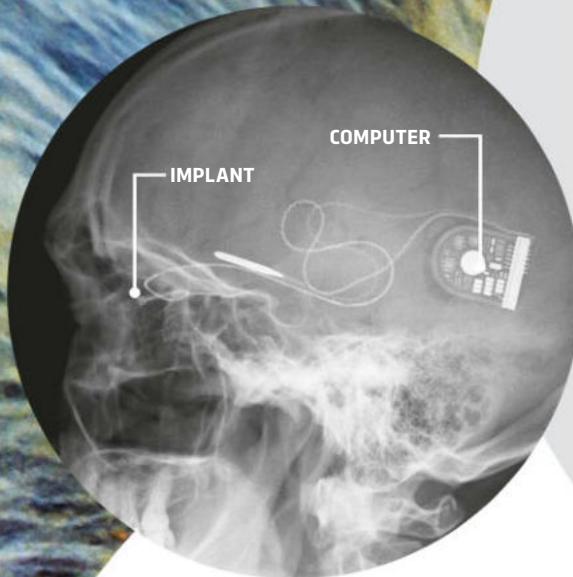
CAN WE FIND A CURE FOR BLINDNESS?

Revolutionary new treatments using genes, stem cells and bionics could bring millions of people's worlds back into focus

WORDS: SIMON CROMPTON

Fear of the dark runs deep. According to a survey by the RNIB, more adults in the UK are afraid of losing their sight than they are of developing Alzheimer's, Parkinson's or heart disease.

But that could change as the seemingly miraculous idea of a cure for blindness becomes reality. Extraordinary progress in electronics, gene therapy and stem cell treatments in the past decade have brought sight to dozens of people who otherwise faced blindness for the rest of their lives. The coming years hold the prospect of stem cell treatments that seed the retina with healthy cells, along with new techniques that transform nerve cells into light receptors. With UK funders and industry investing heavily in research and treatments for blindness, sight restoration for thousands of previously 'incurable' people is becoming a realistic possibility.



BIONIC EYES

Bionic eyes are no longer the preserve of science fiction: they have already transformed the lives of many visually impaired people

Simply put, bionic eyes replace the retina with an electronic version.

Retinal implants, which work the same way as an image sensor chip in a digital camera, have now been implanted into 40 people during trials. They provide basic vision to those who have lost sight through conditions like retinitis pigmentosa, which destroys light-sensitive cells in the eye.

The 3mm chip is inserted into the back of the eye in an operation lasting six to eight hours. In response to light, the chip sends out impulses that stimulate nerve cells behind the retina, which then send signals to the brain via the optic nerve. The device is connected to a tiny computer, implanted behind the ear and powered by a magnetic coil.

For those who have the implant, images are black and white and grainy. The chip only has 1,500 pixels – nothing compared to the iPhone 6's eight

megapixels. But the image is refreshed as the eye moves and the result can be life-changing for those who have spent years without sight.

VISIONARIES

Prof Robert MacLaren, who heads British trials at Oxford Eye Hospital, says that now the implant has been proven to work, investment and improvements will follow. He hopes that the device, which may cost £80,000, will be funded by the NHS.

"Trialling the electronic retina has been an amazing experience for both the team and the patients," he says. "It's been so exciting talking to patients two weeks after switching the device on and hearing what they can see. People have described seeing smiles on faces, food on plates and household objects for the first time in years. It's bringing real results to patients."

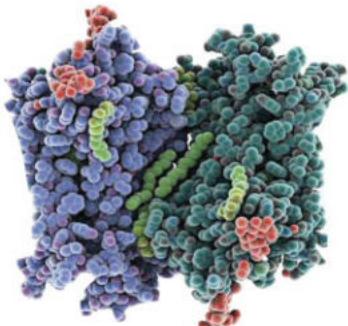
A simpler device called the Argus II has already been approved by US regulators, and is being used by people with retinitis pigmentosa. A camera mounted on glasses relays pictures to a small video processing unit. The resulting signals are transmitted to an array of electrodes attached to the retina, stimulating existing cells to send visual information along the optic nerve to the brain. It is being tested in

the UK for people with age-related macular degeneration (AMD).

And in Australia, scientists are working on a system that bypasses the eye altogether by stimulating regions of the brain associated with vision. This year, researchers at Melbourne's Monash University plan to start implanting a series of 9mm square electronic 'tiles' into the visual cortex of people who have blindness caused by optic nerve damage. Signals from a head-mounted camera are relayed via a video-processing unit to the tiles, which then use microelectrodes to stimulate the brain. The researchers say that the images produced will allow users to navigate and recognise the presence of people and objects.

GENE THERAPY

Viruses aren't always bad – they can be used to deliver healthy genes into cells to slow the progression of inherited eye diseases



ABOVE: Researchers have used the gene that codes for the eye's light-detecting pigment rhodopsin (pictured) to rejuvenate the sight of blind mice

BELOW: The speckled areas on this eye are caused by age-related macular degeneration, which can lead to blindness

According to Prof Robin Ali from the Institute of Ophthalmology at University College London, gene therapy is the most advanced new approach to blindness. "It is bringing fantastic improvements in vision," says Ali. "And now there's huge investment from the pharmaceutical industry, which is investigating a range of products."

VIRTUOUS VIRUSES

Gene therapy uses modified viruses to deliver a healthy gene into a cell that has a mutated version of the same gene. The healthy version takes over, and the cell begins to function correctly. The eye is the perfect location for this type of therapy: it is easy to access and is also partially shielded from the immune system, reducing the likelihood of the

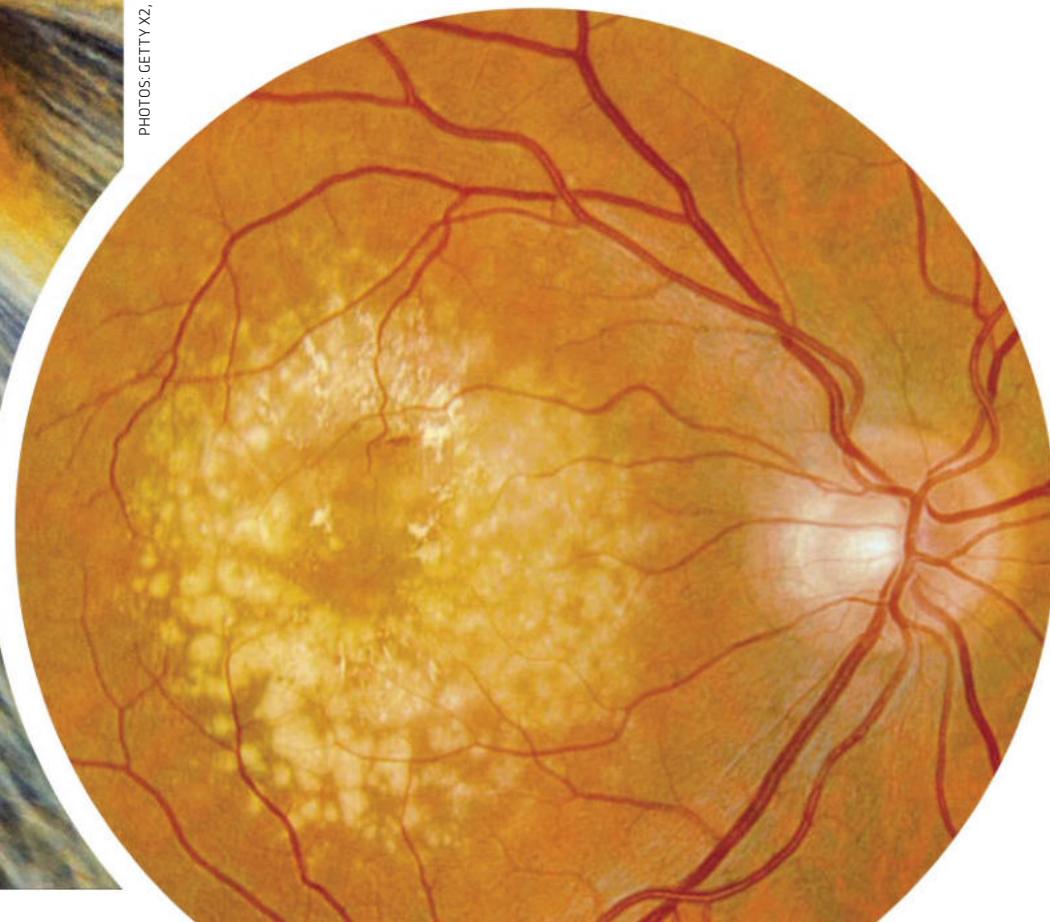
body's defence mechanisms attacking the virus.

Since 2007, the main focus of gene therapy research has been rare inherited retinal diseases, particularly Leber's congenital amaurosis (LCA) and choroideremia. These disorders cause the breakdown of cells in the retina. Studies in the UK and the US have shown that gene therapy can slow deterioration and even improve vision. Approved gene treatments are likely to be available in two years. While there is some indication that the improvements can wane after a few years, many experts believe that now the principles have been demonstrated, there is momentum to perfect the technique and develop it for more common conditions.

The problem is that while scientists know the genes responsible for conditions such as LCA and choroideremia, they do not know the genes contributing to age-related macular degeneration, or to the majority of other eye conditions. The challenge is to find the genes responsible.

SEE THE LIGHT

A more experimental approach to gene therapy called optogenetics is being investigated by researchers in Manchester, Oxford, Paris and Dallas. This has the spectacular potential to help all blindness caused by damage to light-sensitive rods and cones. In experiments on mice with damaged retinas, researchers at Manchester University used viruses to inject the gene that codes for the eye's light-detecting pigment (rhodopsin) into the cells behind the retina. After treatment, previously blind mice could judge the size of objects and discriminate black and white bars. The researchers hope to start trials in humans in five years. ➤



WHAT CAUSES BLINDNESS?

Sight loss isn't the same from person to person

DAMAGE TO RETINAL PIGMENT EPITHELIUM

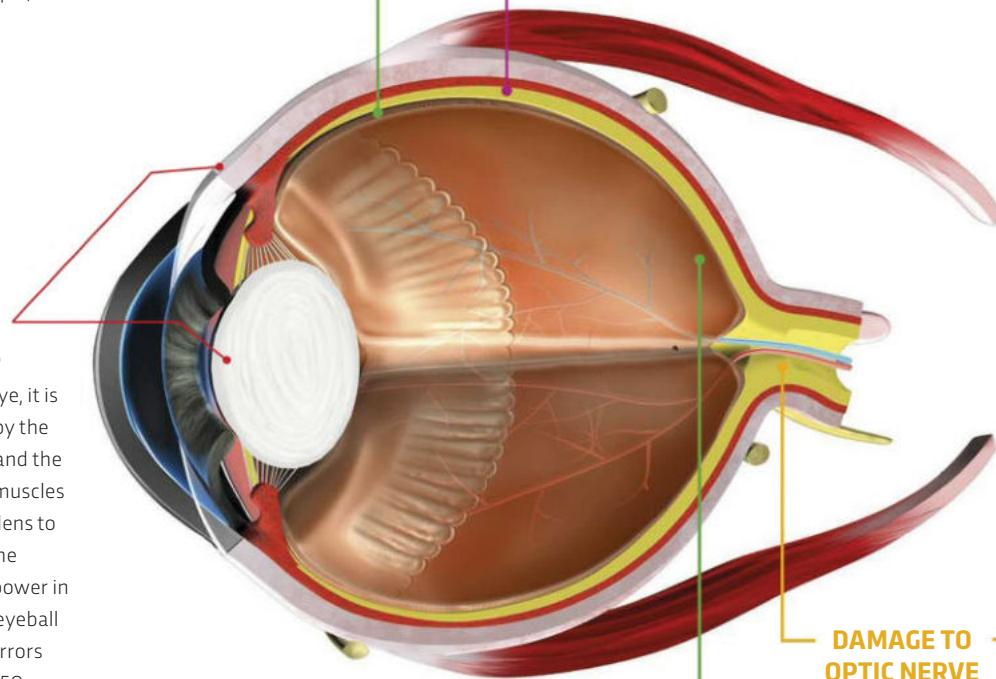
The retinal pigment epithelium is a layer of cells behind the retina that nourishes and maintains photoreceptors. It's attached to a layer filled with blood vessels, the choroid. Damage to the epithelial cells through age-related macular degeneration, for example, can cause rods and cones to die.

RETINAL DISEASES

The retina is the light-sensitive screen of tissue at the very back of the eye. It contains photoreceptor cells called rods and cones. Rods are sensitive to light, dark, shape and movement, while cones are sensitive to colour. Many retinal diseases, including retinitis pigmentosa, damage or destroy the rods and cones.

PROBLEMS WITH CORNEA AND LENS

As light comes into the eye, it is focused onto the retina by the cornea at the very front and the lens within. Supporting muscles change the shape of the lens to focus. Deformations of the cornea, lack of focusing power in the lens and a distorted eyeball can all cause refractive errors that make up more than 50 per cent of cases of partial sight loss or blindness.



MACULAR DEGENERATION

The macula is the central area of the retina where vision is normally sharpest. At its centre is an area called the fovea which has the highest concentration of cones and is responsible for high resolution vision. Macular degeneration causes the photosensitive cells in these vital areas to deteriorate.

DAMAGE TO OPTIC NERVE

Nerves in the retina carry impulses from photosensitive cells to the brain via the optic nerve. Around 1.2 million nerve fibres from the retina converge to form this nerve. Glaucoma, a group of diseases often associated with increased pressure in the eyeball, can damage the optic nerve and cause blindness if left untreated.



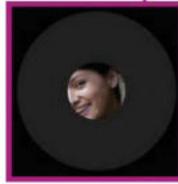
Macular degeneration



Refractive errors



Glaucoma



Retinitis pigmentosa



STEM CELLS

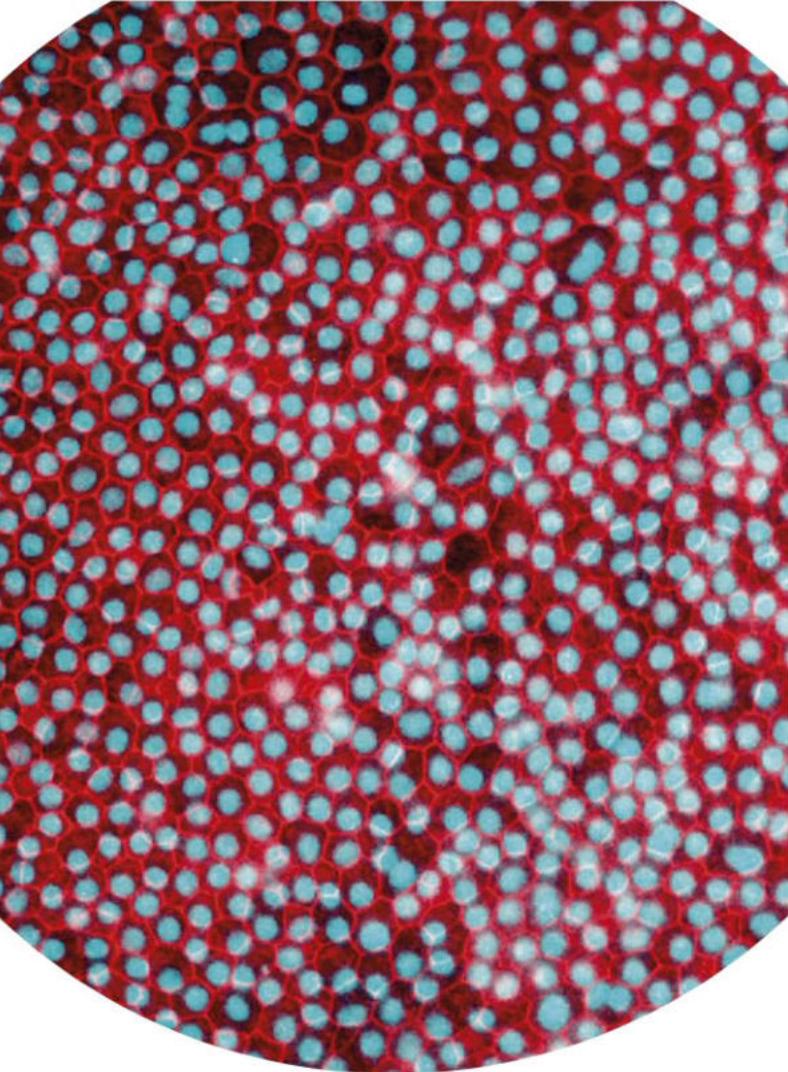
These biological building blocks could reconstruct damaged eyes

Stem cell treatments to repair damage to the cornea at the front of the eye have been successfully trialled in humans for over 15 years and are available in Europe. But it is their potential to cure or prevent problems at the back of the eye, particularly age-related macular degeneration (AMD) and retinitis pigmentosa, that is exciting.

AMD destroys the epithelial retinal pigment cells that nourish the rods and cones in the retina. Therefore when they die, the rods and cones succumb shortly after. Researchers from Moorfields Eye Hospital and University College London are now using donated human embryonic stem cells to grow layers of epithelial retinal pigment cells in the lab. This new healthy layer of cells is then implanted into AMD patients. If successful, the trial could result in a treatment that stops AMD at an early stage – something that seems far away with gene treatments.

STEM CELL SAVIOURS

UK company ReNeuron is about to start trials of a stem cell therapy that may provide a way of regenerating sight even when rods and cones



have died. It has developed a line of human retinal progenitor cells which, when implanted into the retinas of animals, start to form new rods and cones. This presents the possibility that people blinded by conditions such as retinitis pigmentosa may regain their sight.

"There's excitement in the UK about the possibility of fast-tracking these therapies as quickly and safely as possible into the NHS," says leading stem cell researcher Prof Pete Coffey. "The UK government has put a big investment into this area through the Cell and Gene Therapy Catapult and the UK Regenerative Medicine Platform – two big funding bodies which will push these therapies if they deliver on their promise."

ABOVE LEFT:
Age-related
macular
degeneration is a
painless eye
condition that
causes a dark or
blurred area in the
centre of vision

ABOVE: Embryonic
stem cells were
used to create
these retinal
pigment cells,
which could be
used to restore
eyesight in blind
patients

PHOTOS: GETTY X4, SCIENCE PHOTO LIBRARY X2

Simon Crompton is a science journalist and former health editor for both *The Times* and *The Daily Telegraph*.

DISCOVER MORE

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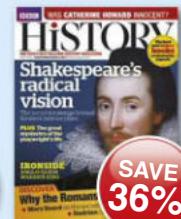
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ROBERT MATTHEWS... **THE STATISTICS CRISIS**

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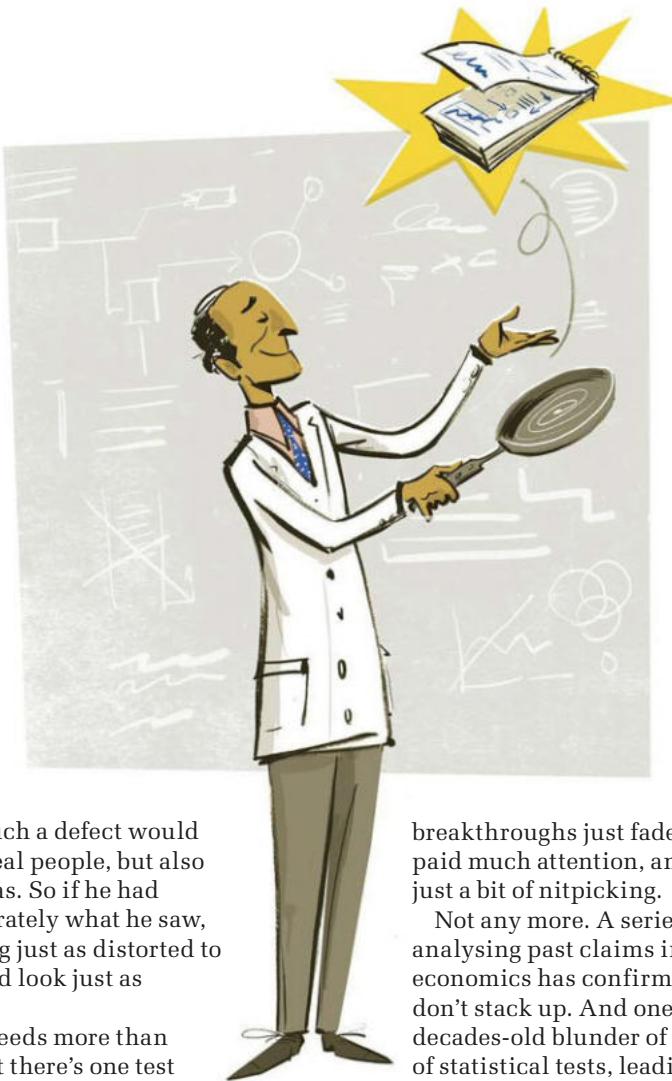
the Nobel-prizewinning immunologist Sir Peter Medawar back in the 1970s. The works of the 16th-Century artist El Greco often show people looking oddly tall and thin. Was this deliberate, or the result of a visual defect making him see the world like this?

According to Sir Peter, anyone who can instantly see that the dodgy eyesight theory is wrong is definitely smart. It requires spotting in a flash that such a defect would affect not just how El Greco saw real people, but also his depiction of them on the canvas. So if he had simply been trying to record accurately what he saw, the result would be figures looking just as distorted to him as the real thing, which would look just as undistorted to the rest of us.

As Sir Peter admitted, science needs more than people who can ace such tests. But there's one test I'd argue every wannabe boffin should be able to pass, not least because it highlights a key issue that occurs repeatedly in research. Indeed, it's at the heart of a huge crisis of confidence sweeping through science.

It goes as follows. The chances that someone with a brain tumour gets recurrent headaches are over 50 per cent. So if you get recurrent headaches, the chances you've got a brain tumour are also around 50 per cent, right? Wrong, of course, but can you say why? It's because the argument assumes the chances of A given B are identical to the chances of B given A. And you can't flip probabilities around like that. If you spotted it, then you're head and shoulders above generations of researchers who either failed to notice or chose to ignore it when analysing their data.

The problem lies with a statistical technique known as 'significance testing'. Put simply, this allows



Robert Matthews is visiting professor in science at Aston University, Birmingham. His latest book *Chancing It: The Laws Of Chance And What They Mean For You* is out now (£14.99, Profile).

DISCOVER MORE

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NEXT ISSUE: HIPPIES AND QUANTUM WEIRDNESS

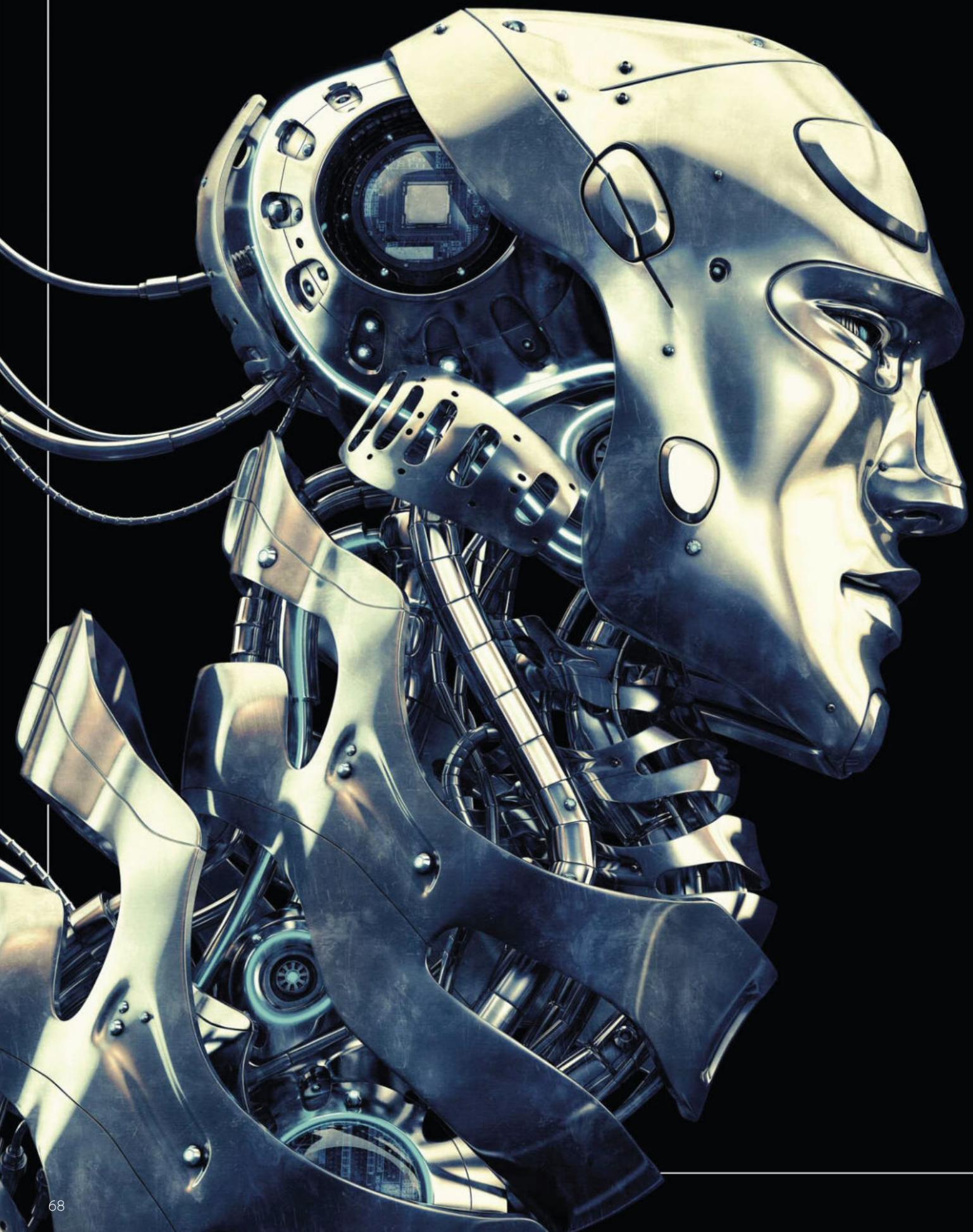
researchers to work out the chances of getting at least as impressive results as they did, assuming just fluke were responsible. The trouble is, generations of researchers have then flipped the result around, believing that it reveals the chances of their 'breakthrough' actually being a fluke.

Statisticians have been warning researchers about this howler for decades. I've been writing about it since the late 1990s, in academic journals, newspapers and *BBC Focus*. Like others, I've suggested it could play a role in the disturbing way many breakthroughs just fade away over time. Yet no one paid much attention, and it seemed to be regarded as just a bit of nitpicking.

Not any more. A series of international studies analysing past claims in medicine, psychology and economics has confirmed that a substantial proportion don't stack up. And one of the prime culprits is that decades-old blunder of flipping round the outcome of statistical tests, leading researchers to see 'significance' in baloney.

There are signs that the scientific community is waking up to the need for action. The American Statistical Association recently issued a public statement about the 'misconceptions and misuse' of significance testing and called for researchers to move towards more sophisticated methods.

So will they? Only if they're willing to take another test, this time centred on the biggest question facing researchers today: what is science about, getting results that are reliable, or merely publishable? ☺



Why haven't we found alien life?

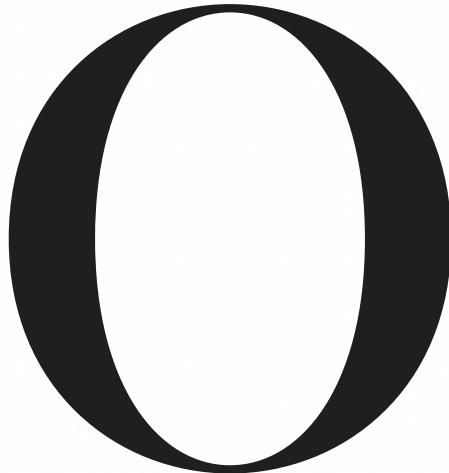
FOR DECADES, ASTRONOMERS HAVE BEEN SCOURING THE SKIES FOR BIOLOGICAL FORMS OF INTELLIGENT LIFE. BUT SHOULD THEY BE LOOKING FOR SOMETHING COMPLETELY DIFFERENT?

WORDS: ASTRONOMER ROYAL MARTIN REES

COMPLEMENTS
ALIENS:
THE BIG THINK

BROADCAST ON





ver the last 20 years, we've come to realise that most stars are orbited by retinues of planets. Within our Milky Way, there are millions – even billions – of planets that resemble the young Earth. But do these planets contain life? Now that's a tricky question, as we don't even know how life began on our own planet – what caused the transition from complex chemistry to the first replicating entities deemed to be 'alive'?

On other planets in the Universe, we don't know how likely it is that evolution led to the appearance of 'intelligent' creatures with technical capabilities, as it did here on Earth. But if intelligence did emerge on some of these worlds, then everything could have had a headstart if it developed on a planet orbiting a star older than the Sun, or life could simply have evolved at a faster pace than it did here on Earth. Consequently, life elsewhere could have already achieved capabilities far exceeding our own. And

this is the thinking behind a renewed interest in seeking evidence for aliens.

Russian entrepreneur and physicist Yuri Milner has committed \$100m over the next decade to upgrading searches for extraterrestrial intelligence with the launch of the Breakthrough Listen project, which will survey the 1,000,000 closest stars to Earth. I'd rate the chances of success as, at best, a few per cent. But a detection would be so important – not just for science, but for our perception of humanity's place in the cosmos – that it's surely worth the gamble.

We should be open-minded about where life might emerge and what forms it could take.

"The habit of referring to 'alien civilisations' may be too restrictive. ET might be a single integrated intelligence"

But it plainly makes sense to start with what we know and to deploy available techniques to discover whether any of these planets have atmospheres that display evidence for any life at all. Clues will surely come, in the next decade or two, from high-resolution spectra of planets, using the James Webb Space Telescope and the next generation of ground-based telescopes that will come online in the 2020s. And biochemists may soon crack the problem of life's origins. They can then tell us how likely it is for life to appear in the first place, where the optimal locations are to search for extraterrestrial life, and whether it would be based on DNA or RNA like life on Earth, or whether it could have quite different chemistry.

Conjectures about advanced or intelligent life are far more shaky than those about simple life. The firmest guesses that we can make are centred on what has happened on Earth, and what might develop from Earth-based life in the distant future.

SEARCHING FOR A SIGNAL

It would plainly be a momentous discovery to detect an artificial 'signal': it would indicate that there are entities elsewhere in the cosmos showing evidence of intelligence and technology. But what might the originators of the signal be like? In popular culture, aliens are generally depicted as vaguely humanoid and generally bipedal, though maybe with tentacles, or eyes on stalks. Perhaps such creatures exist. But I would argue that they aren't the kind of aliens that we should be expecting. I think an ET signal, if we were to find it, would come not from biological life but from immensely intricate and powerful electronic brains. In particular, the habit of referring to 'alien civilisations' may be too restrictive. A 'civilisation' implies a society of individuals: in contrast, ET might be a single integrated intelligence.

I draw this conclusion from what we know about how intelligence emerged on Earth, and – more importantly – on how we expect it to evolve in the ➤



1

1 Back in 1835, the Great Moon Hoax depicted humanoid aliens with bat-like wings

2 1951's *The Day The Earth Stood Still* featured the robot, Gort – could this be a more realistic portrayal of real-life aliens?

3 Since the early 1900s, we have thought of aliens as vaguely humanoid with large eyes and grey skin, like those in the Roswell hoax

4 Rather than little green men, alien life could be closer to the Borg, a machine-based hive mind that terrorised the *Star Trek* universe aboard their cube-shaped craft



2



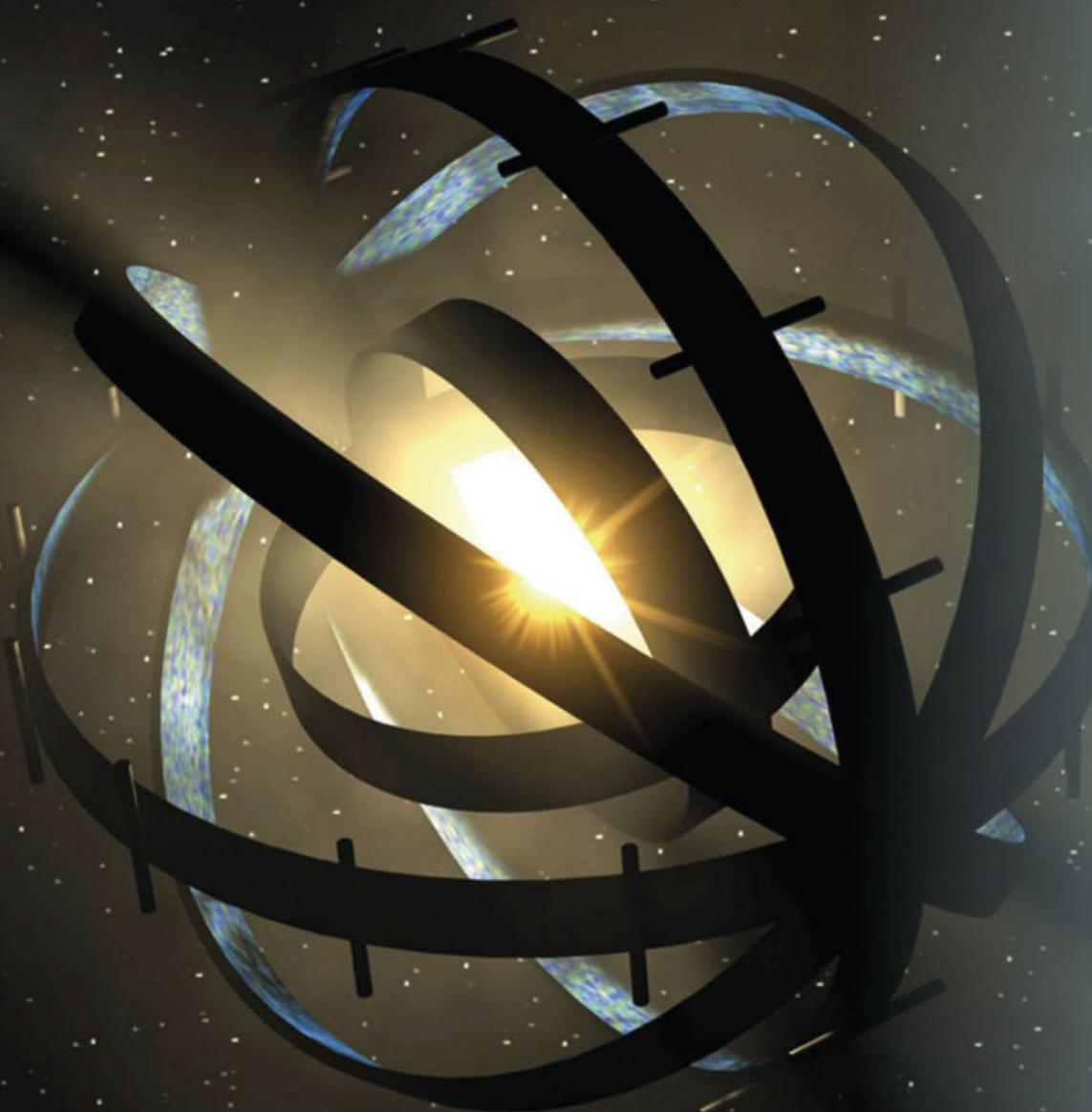
3

PHOTOS: ALAMY X2, KOBAL COLLECTION, CORBIS/SPLASH NEWS



4

A Dyson sphere concept, popularised by physicist Freeman John Dyson, captures all the solar power from a star. He proposed that if we hunted for structures like this, we could find advanced alien life.



billions of years lying ahead. Let's not forget that, though Earth has existed for 4.5 billion years, the Sun is less than halfway through its life, so future evolution – the post-human era – could extend billions of years into the future. Moreover, the Universe was already more than nine billion years old when the Sun formed. There are many stars that are older, and life on a planet orbiting one of these would have had a headstart over us.

There's been a changing perspective on the future of life on Earth that's relevant to any discussion about the search for extraterrestrial intelligence. Recent advances in computers and robotics have led to growing interest in the possibility that artificial intelligence could in the coming decades achieve (and exceed) human capabilities over a wider range of conceptual and physical tasks. This is leading to a greater understanding of learning, thinking and creativity that has stimulated debate on the nature of consciousness. It has also led to some fascinating speculation by ethicists and philosophers on what forms of artificial intelligence might be created by us – or might already exist in the cosmos – and how humans might relate to them.

RISE OF THE MACHINES

Few doubt that machines will gradually surpass more of our distinctively human capabilities, or enhance our capabilities via cyborg technology. Disagreements, when they occur, revolve around the rate of advance. Some think that there will be an 'intelligence explosion' during this century, while the cautious think these transformations may take hundreds of years. Either way, the timescales are rapid when compared to those of the Darwinian evolution that led to the emergence of humans.

There are chemical and metabolic limits to the size and processing power of brains. Maybe humans are close to these limits already. But there are no such constraints on electronic computers (still less, perhaps, on quantum computers). For these, the potential for further development could be as dramatic as the evolution from single-celled organisms to humans. The amount and intensity of 'thinking' that's done by organic human-type brains will be utterly swamped by the 'intellect' of machine-based AI.

But what are the more immediate steps towards this long-term future? During this century, the entire Solar

System – planets, moons and asteroids – will be explored by flotillas of tiny robotic craft. The next step would be the deployment of robots capable of constructing and assembling enormous structures in space – huge gossamer thin mirrors or vast computer networks, for instance.

There will never be mass migration of humans from the Earth, but some brave adventurers may establish small communities elsewhere in the Solar System – though they'll find nowhere even as comfortable as the South Pole or the ocean bed. Nonetheless, human exploration will be restricted to our Solar System. The transit time to 'Earths' orbiting other stars, using known technology, far exceeds a person's lifetime. Interstellar travel – other than unmanned probes, DNA samples, and so on – is therefore an enterprise for post-humans. They could be silicon-based, or they could be organic creatures (or cyborgs) who had won the battle with death, or perfected hibernation or suspended animation.

WHAT'S OUT THERE?

Earth's biosphere is far from optimal for advanced AI. Interplanetary and interstellar space, a hostile environment for humans, will be the preferred arena where non-biological 'brains' may, in the far future, construct huge artefacts by mining moons and asteroids. And where these post-human intellects will develop is as far beyond our imaginings as string theory is for a mouse.

But what might be out there already? Suppose that there are many other planets where life began, then suppose that on some of them Darwinian evolution followed a similar track to what happened here on Earth. Even then, it's highly unlikely that the key stages would be synchronised. If the emergence of intelligence and technology on a planet lags significantly behind what has happened on Earth (because the planet is younger, or because the 'bottlenecks' to complex life – from single cell to multicellular organisms, for instance – have taken longer to negotiate than here on Earth) then that planet would plainly reveal no evidence of extraterrestrial life. But life on some planets could have developed faster or earlier.

The history of human technological civilisation is measured in centuries. It may be only one or two more centuries before humans are overtaken or eclipsed by inorganic intelligence, which will then persist, continuing to evolve, for billions of years. This suggests that if we were to detect ET, we would be most unlikely to 'catch' alien intelligence in the brief sliver of time when it was still in organic form. It's far more likely that it would have long ago transitioned into electronic (and inorganic) forms.

What does this mean for hunts for extraterrestrial intelligence? Despite the heavy odds against success, these searches are surely worthwhile because the stakes are so high. That's why we must acclaim the ➤

"Where post-human intellects will develop is as far beyond our imaginings as string theory is for a mouse"

RIGHT: Could the Milky Way be full of alien civilisations, going about their daily business in their planets' cities? Or are we truly alone?

BELOW: Green Bank (pictured) along with Parkes in Australia will have 20 to 25 per cent of its time dedicated to Breakthrough Listen



PHOTOS: GETTY, SCIENCE PHOTO LIBRARY

● launch of the Breakthrough Listen project, which will carry out the deepest and broadest search for alien technological life. Two of the world's biggest steerable radio dishes – Green Bank in Virginia in the US and Parkes in Australia – will each have 20 to 25 per cent of their time dedicated to the project. Hopefully, other instruments such as the Arecibo Observatory (the huge radio telescope dish carved in the ground in Puerto Rico) will join the quest. These telescopes will be used to search for non-natural radio transmissions from nearby and distant stars, from the plane of the Milky Way and its centre, and from nearby galaxies. They will seek narrow-band emissions of a kind that couldn't arise from any natural cosmic source. They will search over a wide frequency range from 100MHz to 50GHz using advanced signal-processing equipment developed by a team centred on UC Berkeley.

ALIEN INVESTIGATION

The Breakthrough Listen project builds on a tradition of radio-astronomical searches for extraterrestrial intelligence stretching back 50 years. But of course there could be evidence in other frequencies too. For instance, laser pulses would be a good way to communicate over interstellar distances. And powerful laser beams offer a possible advanced technique for accelerating spacecraft to high speeds.

These would be even more conspicuous. And that's why the project will use optical telescopes as well.

Searches for extraterrestrial intelligence seek out electromagnetic transmissions – in any band – that are manifestly artificial. But even if the search succeeded (and few of us would bet more than 1 per cent on this), I think it's unlikely that the 'signal' would be a decipherable message that was intentionally aimed at us. It would more likely be just a by-product (or even a malfunction) of a highly complex machine far beyond our comprehension that could trace its lineage back to alien organic beings. These beings could still exist

on their home planet, or they might long ago have died out.

The only type of intelligence whose messages we could decode would be the (perhaps small) subset that used a technology attuned to our own concepts. Even if signals were being intentionally transmitted, we may not recognise them as artificial because we may not know how to decode them. So we may fail to recognise a meaningful message even if it's detected.

Even if intelligence were widespread in the cosmos, we may only ever recognise a small and atypical fraction of it. Some 'brains' may package reality in a fashion that we simply can't conceive. Other forms of alien life could be living a contemplative existence, deep under some planetary ocean or floating freely in space, doing nothing to reveal their presence.

EARTHLY IMPORTANCE

Perhaps the Milky Way already teems with advanced life, and our descendants will 'plug in' to a galactic community as rather 'junior members'. On the other hand, our Earth may be completely unique and the searches may fail. This would, of course, disappoint the searchers. But there would be an upside too, and that would be that humans could be less cosmically modest. Our tiny planet – this pale blue dot floating in space – could be the most important place in the entire cosmos. Moreover, it would mean that we are living at a unique time in our planet's history: our species would have cosmic significance, for being the transient precursor to a culture dominated by machines, extending into the future and spreading far beyond Earth. Even if we are now alone in the Universe, this wouldn't mean that life would forever be a trivial 'pollutant' of the cosmos. Our planet's future would then be of extreme cosmic importance, not 'merely' a matter of concern for us humans.

The Breakthrough Listen project may not settle this momentous question. But it gives us a small chance of doing so – and the stakes are so high that even a small chance is worth far more than zero. ↗

Lord Martin Rees is a cosmologist and astrophysicist. He is the current Astronomer Royal, and is visiting professor at University College London and the University of Leicester.

DISCOVER MORE

To watch clips from BBC Four's *Aliens: The Big Think*, visit bit.ly/the_big_think

"We would be most unlikely to 'catch' alien intelligence in the brief sliver of time when it was in its organic form"

SUMMER OF SPORT

TECH WISH LIST

All the incredible, high-end gadgetry you could wish for to enjoy this summer's packed sporting schedule

WORDS: JAMIE CARTER



Play smart

Inspired by Wayne Rooney and co? Then you need the ultimate 'wear-a-ball' device for Euro 2016! Adidas miCoach Smart Ball has an integrated sensor that detects speed, spin, strike and flight path, then relays your kick data to a miCoach smart ball app on your phone. Back of the net!

£145, adidas.co.uk

Extreme screen

Sport brings out the best in people, and that applies to technology, too. Here, home cinema and interior design team up to create an invisible screen. Using a laser diode and Sony's own SXRD panels, which offer higher contrast, the Sony LSPX-W1S ultra short throw projector produces an Ultra HD 4K projection (four times the resolution of Full HD) a little under 4m wide from just 17cm away.

£34,000, sony.co.uk/pro





**BRING
OUT THE
BURGERS**

Proper grilling

There's a lot at 'steak' this summer, but at least Lynx's SmartGrill has got your food covered. The freestanding gas grill measures just over a metre across, auto-cooks food and sends a message your phone when it's ready, but it can also be voice-activated. Besides, how often do you find a barbecue that boasts Wi-Fi, 64GB of storage and compatibility with iOS and Android phones?

\$9,499 (£6,570 approx), lynxgrills.com

In a bubble

Sport is all about making the most of what you've got. That applies to beer, too; the one-button Sonic Foamer uses ultrasonic waves to excite the bubbles in beer – particularly real ales and craft beers – creating a foamy head and releasing the aroma. Result.

\$29.99 (£21 approx),
sonicfoamer.com

**Party time**

Though ideal for streaming the radio commentary from an app on your phone, the sound quality of the wireless Mu-so Qb Bluetooth speaker is wasted on speech. Since it's capable of receiving tunes from a phone wirelessly via Apple Airplay, Spotify Connect and Bluetooth, it's even better for the post-match celebration party.

£595, naimaudio.com

**Cut the noise**

Designed for frequent flyers, Bose's QuietComfort 20i Acoustic Noise Cancelling earphones block out almost all ambient sound, making them perfect for listening to commentaries in stations and on packed commuter trains. The battery charges in just two hours, delivering quiet times for 16 hours straight.

£229.95, bose.co.uk

Touch and go

Tablets tend to get slimmer with every passing year, so the book-sized ZTE Spro Plus smart projector is initially a shock. But tucked in alongside its 20cm screen are a laser HD projector and 4W speakers that together provide a cute way of watching up to six hours of action while on the move – and at up to 2m in size.

£TBC, ztedevice.com

**Drink up**

With Euro 2016 and other high-profile sporting events taking place at the hottest time of year, some serious (but responsible!) refreshments will be in order. The world's first automated home brewery could help. Brewie's concept is simple: make any craft beer at the touch of an app on a phone. Just select a pre-installed beer recipe, add the ingredients, and Brewie takes care of everything from mashing and boiling to hop addition and cooling. Cheers!

\$1,849 (£1,250 approx),
brewie.org

**BECOME
A
BREWER**





Bang up the bass

Whether it's the tension on the tennis court or the roar of the Stade de France, it's not the size of your TV but the quality of your speakers that will make the hairs on the back of your neck stand up. At a bone-shaking 8,200W, Bang & Olufsen's BeoLab 90 speakers are capable of much more than that. Eighteen speaker drivers create head-spinning sound, though the price achieves that effect on its own.

£55,199 per pair, bang-olufsen.com



Get juiced

If you're checking scores, stats and other television channels on your phone during events, it's going to need a battery boost sooner or later. This TV stand not only holds a big screen, but has built-in Qi inductive charging tech to refuel compatible Android phones from the likes of Samsung, LG, HTC, Sony and Motorola.

£1,680 approx, loewe.tv

Souped-up sport

The great value W1070+ short-throw projector from BenQ can create a 2.5m image from just 2.5m away. It's compact, lightweight and easy to set up, but the highlight is its 2200 ANSI Lumens lamp, which means its images are bright enough for those lunchtime kick-offs, even with the curtains open.

£600, benq.co.uk



Chill out

Want the best seat in the house? Some think home cinema is all about films, but this summer is likely to prove otherwise. The Premiere Home Cinema Chair has a built-in drinks cooler, a massage system to soothe any tension during close matches, and a motorised recline for when you need to take a half-time nap.

£1,299, drinkstuff.com

Sports marathon

In 2012, millions of Brits used laptops, phones, tablets and smart TVs to watch the BBC's 'Red Button' streams of the sport. Yet all that information streaming to a mobile device can drain the battery faster than a serve by Andy Murray. Lenovo's Yoga Tab 3 comes with 15 hours of battery life, letting you binge on beach volleyball and boxing for an entire day.

£179.99, shop.lenovo.com





Snacks on standby

If you're planning to watch all the action a long way from the kitchen, a minibar fridge is a must. The retro-style Smeg FAB5 mini fridge takes 40 litres over two adjustable shelves. As well as an ice cube tray, there's also a snack compartment for half-time, while at 39 decibels it's quieter than most.

£629, smeg.com



Stay secure

Will you be barricaded inside, consumed by sport? The Canary Full HD security camera is motion-sensitive, so starts filming when it sees something odd. It then sends an alert to your phone, so you can watch recorded video and audio of what happened without even budging from the telly.

£159, maplin.co.uk

Space saver

The Screen Innovations Black Diamond motorised projector screen has physics on its side: its clever fabric absorbs ambient light in daylight so you can watch anything, anytime (which is why there's a similar screen on the International Space Station). At the touch of a button the screen retreats into a tube, which is itself suspended by a cable, for a unique (and expensive) 'floating' look.

£6,500, screeninnovations.com

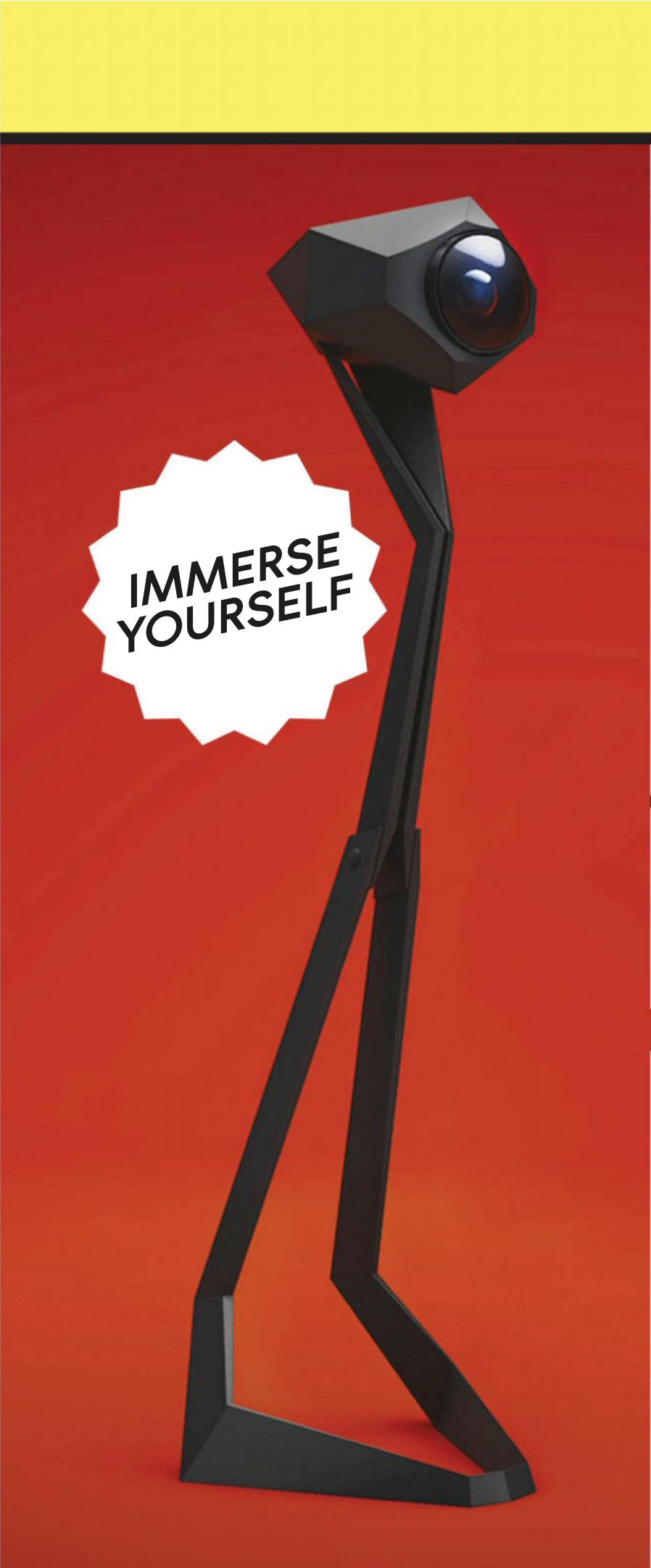


Bionic buddy

While 2016's summer of sport will be unrivalled in excitement, there will inevitably be some disappointment and bitter regrets. What better way to bounce back than with your very own robot butler? Due to appear in autumn, the Segway Robot is something of a hybrid: you can use it as a regular scooter, but it can also answer the front door, fetch your shopping and keep you company. Able to respond to voice commands, it can record video, take photos, and use its three cameras for depth-sensing. New balls please, Segway slave!

£TBC, robot.segway.com





IMMERSE
YOURSELF



Rush-hour radio

Driving home from work will almost certainly clash with Euro 2016's daily 5pm kick-off times, and there's no telling when Andy Murray will be playing on centre court. Pure's Highway 600 DAB radio sits neatly on your dashboard, connects to the speaker system, and doubles up as a hands-free kit.

£150, pure.com

Love the LEDs

Those after a good value, big screen TV for the sporting summer should investigate this whopping 139cm LED TV from Philips. As well as a Ultra HD 4K resolution screen, the 55PUT6400 runs on Android, so you can download Google Play apps and use Google Cast to send things from an Android phone to the TV. £800, philips.co.uk



Full-on footy

Who really wants to wear those bulky virtual reality goggles? The Immersis VR projector from Catopsys ditches the lonely world of head-mounted displays to project a field-of-vision-filling 180°, Full HD image around a room. Some call it 'augmented reality', others 'mixed reality', but this concept of total immersion in panoramic video is all about going beyond the TV screen. It's set for a July 2016 release.

€2,250 (£1,747 approx),
immersisvr.com

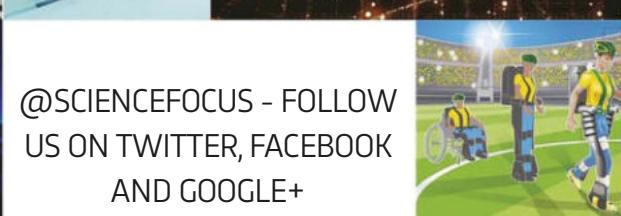
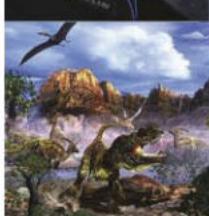
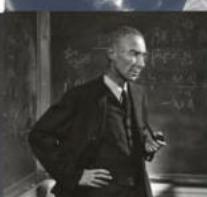
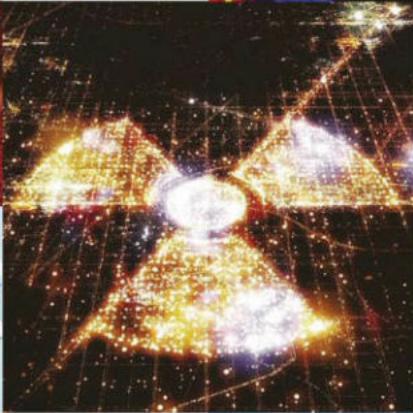
Jamie Carter is a freelance technology and travel writer.



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Q & A



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YOUR QUESTIONS ANSWERED

JUNE 2016

EDITED BY EMMA BAYLEY

What are the most sophisticated drones capable of?

TOM FISHER, LEEDS



The Taranis drone: expected to enter military service in 2030

Drones are radio-controlled flying gadgets with several propellers that may be used for filming, racing, and in the future perhaps even widespread delivery of parcels. Military drones resemble small

aircraft with no pilots. Some can take off, fly and land by themselves. They can perform surveillance over enemy territory or even deploy missiles to attack specific targets in dangerous places where we may not

want to risk human pilots. One of the most advanced today is the Taranis, a UK-built drone with a top speed of 1,127km/h (700mph) and 9.7m wingspan that is nearly invisible to radar. **PB**



Foot cheese: not
tasty on a cracker

Why do sweaty feet smell of cheese?

JO DRYSDALE, BRISTOL

The same bacteria that is used to ripen many cheeses, including Munster, Limburger and Port-du-Salut, also lives on our skin and eats dead skin cells. It's called *Brevibacterium*; as it digests it gives off S-methyl thioesters, which smell cheesy. Another skin-munching bacterium is *Staphylococcus epidermidis*, which produces the cheesy, vinegary-smelling isovaleric acid. The final ingredient in this 'cocktail' is *Propionibacterium*, which converts sweat into the sour-smelling propanoic acid. **LW**

What are supercomputers used for?

RACHEL MELLISH, BROMLEY



Tianhe-2 is the world's fastest supercomputer – bet its developers won't let you play *Pac-Man* on it...

The best supercomputers fill rooms, cost millions, and are thousands of times faster than your computer at home. They are usually used for complex scientific problems involving lots of maths. They are used to predict the weather, model brains, or help predict the result of a nuclear explosion, for example. Some are used to test the strength of

encryption (computer security) methods. They have been used to model the spread of swine flu, to predict climate change, and even to understand the Big Bang at the beginning of the Universe. But technology moves quickly. A top-end desktop computer today calculates at the same speed as a supercomputer 10 years ago. **PB**

How do aquatic snails breathe?

MARY LYONS, READING

Most species of aquatic snail have a comb-like gill. The oldest groups have two gills but the majority have lost one, to make room inside their spiral shell. As snails moved to the land, they swapped gills for a primitive lung, called the pallial cavity. Some snail groups moved back to freshwater and a few re-evolved external gills. Others stay close to the surface and use a snorkel tube to gulp air now and again. Pond snails mostly breathe air but can flood their pallial cavity and use it as a basic gill when their pond freezes over. **LW**

IN NUMBERS

1.2 grams

The amount of salt that can be present in one low-fat blueberry muffin.

14,000

The number of years ago that blue eyes first appeared in humans.

74

The height, in metres, of the world's tallest slide, opening in London in June.



Why did humans evolve a sense of humour?

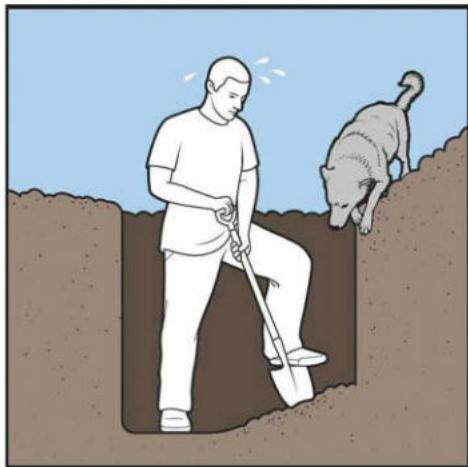
MILLY KINGHORN, ABERDEEN

A recent theory holds that humour evolved because it encourages us to perform the arduous task of fact-checking our assumptions about other people's intentions and perspectives. By this account, mirth is the reward we get when we debunk one of our presumptions and see things suddenly in a new light – jokes are 'super-normal stimuli' that exploit

this system. Once it evolved, humour became a social signal – we assume funny people are intelligent and friendly, and men and women alike prefer witty partners. On average, however, men tend to be more concerned that would-be partners will find their jokes funny, whereas women are more attracted to people who make them laugh. **cj**

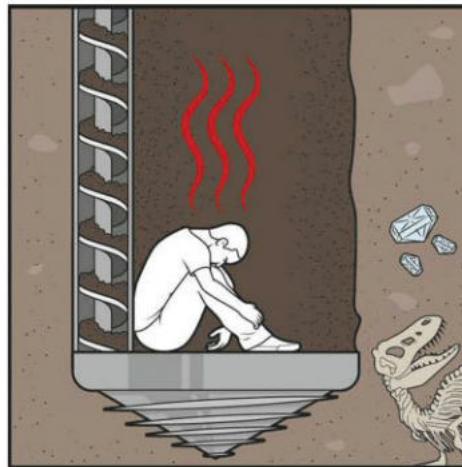
THE THOUGHT EXPERIMENT

IF I DUG DOWN AT 1M/S, WHAT WOULD KILL ME FIRST?



1. EXHAUSTION

Let's say you dig a 1x1m hole, which gives you enough room to wield a shovel. For each metre that you dig down, you have to remove a cubic metre of earth, weighing 1.6 tonnes. Even if you have some kind of bucket elevator so that you don't need to lift the soil to the surface, you're still shovelling almost 100 tonnes a minute.



2. HEAT

Maybe instead of manual shovelling, all the digging is taken care of by an automatic drilling machine that you stand on. But for every 40m that you descend, the temperature will rise by 1°C. After 33 minutes you are 2km deep, and you die of heatstroke in the 50°C air.



3. SUFFOCATION

Even if you have some kind of amazing cooling system, you are still in an ever-deepening hole with almost no fresh oxygen diffusing in through the narrow opening at the top. After a couple of hours of effectively rebreathing the same air, you'll die of CO₂ poisoning at a depth of 7km. Or whenever your bottled air runs out.

Why do dogs bury bones?

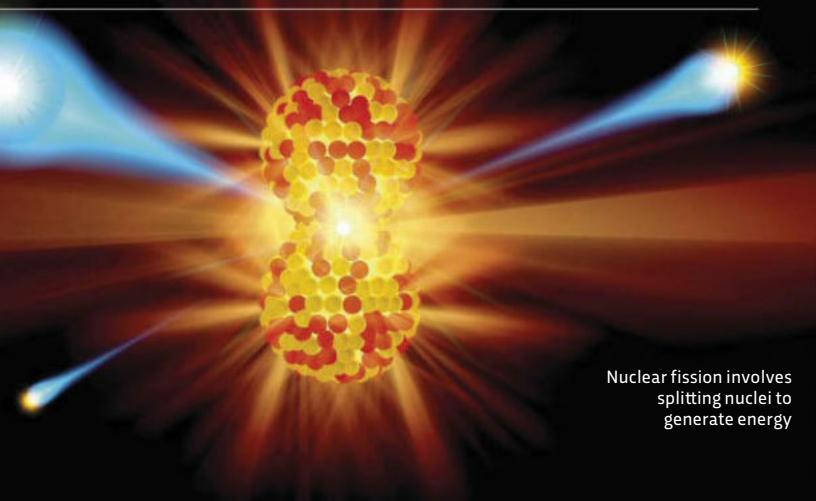
JARED PATERSON, YORK

Wolves bury food that they can't eat immediately. This keeps it safe from scavengers like crows and the cold ground helps to preserve it. Birds don't have a good sense of smell so they find it harder to locate these buried caches than wolves do. Dogs retain this behaviour and will bury toys or bones – either because they are saving their leftovers, or just because they are bored. **lv**



Why do both fission and fusion release energy?

HENRY PARR, BRISTOL



Nuclear fission involves splitting atomic nuclei, and is the process used in nuclear power stations. Fusion, as its name suggests, involves fusing nuclei and is the power source of the stars. While both fission and fusion release energy, the process and amount is very different. Fission exploits the instability of nuclei of heavy elements like uranium, which can be split using neutrons, producing fragments with a lower total mass.

The difference appears as energy – courtesy of $E=mc^2$ – which is carried away by fast-moving neutrons. In contrast, fusion involves ramming together nuclei of light elements like hydrogen so violently they fuse together, producing fresh nuclei plus neutrons. Again, the lower mass of the fusion products is turned into energy via Einstein's famous equation, but over 10 times the amount produced by fission for each gram of 'fuel'. RM



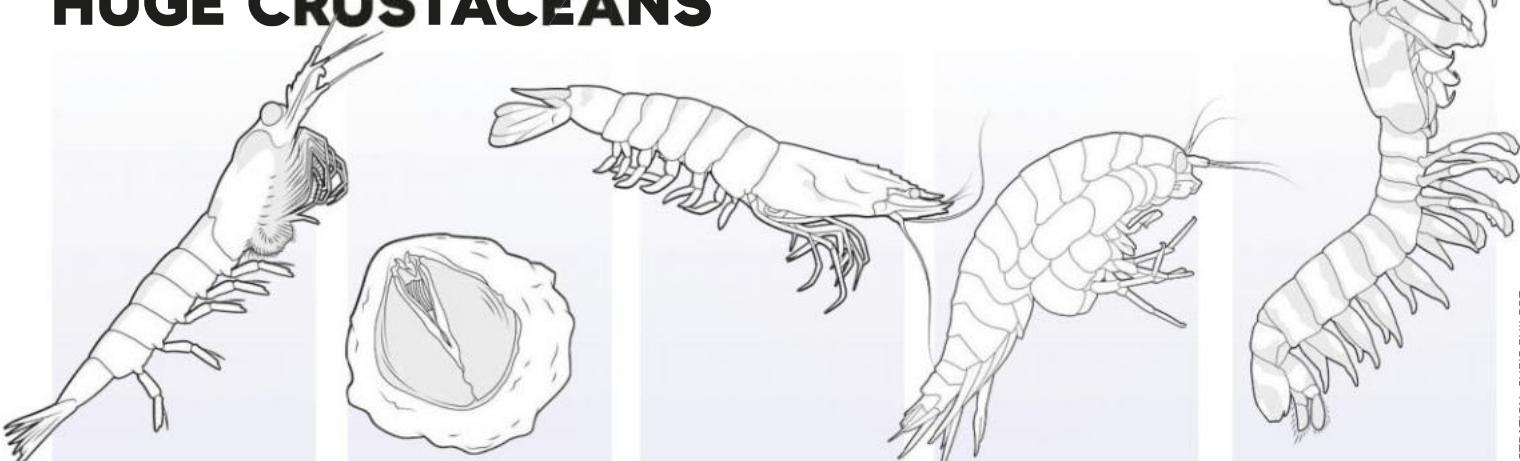
Does sunshine really make us happier?

CLAIRE RENNICK, GLASGOW

When it's sunny, it seems like people are happier – we fill the parks and beaches, and radio stations start blasting out upbeat tunes. And yet, research has repeatedly failed to find any evidence that people who live in sunnier places enjoy more positive moods. A new, massive study published this year even brought into question the idea that a lack of sunshine can lead to seasonal affective disorder (SAD). Nearly 35,000 US adults completed a mood survey at different times of year and there was no evidence of more depression symptoms among those who completed the survey in winter. □

TOP 10

HUGE CRUSTACEANS



10. Euphausiid (krill)

Length: 15cm

Distribution: Antarctic Ocean

9. Giant acorn barnacle

Length: 30cm

Distribution: Coast of northwest America

8. Giant tiger prawn

Length: 33cm

Distribution: Indian Ocean and West Pacific

7. Alicella gigantea

Length: 34cm

Distribution: Kermadec Trench, New Zealand

6. Zebra mantis shrimp

Length: 40cm

Distribution: Indo-Pacific region

WINNER!

Betty Gosling wins an RAC O3 dash cam. The device fits onto your rearview mirror and records the road in HD video, and includes speed alerts and lane diversion warnings too (£159.99, proofcam.com).



"Who're you calling identical?"

Do identical twins have identical genes?

BETTY GOSLING, ESSEX

They start with identical genes, because each is formed from a single fertilised egg that splits into two embryos. But from that moment onwards, their DNA begins diverging. The DNA replication mechanism

introduces about one new mutation for every 100 million base pairs copied, per generation. There are around three billion base pairs in the human genome, so you would expect between 10 and 100 new mutations per person that occur early enough in embryonic development to

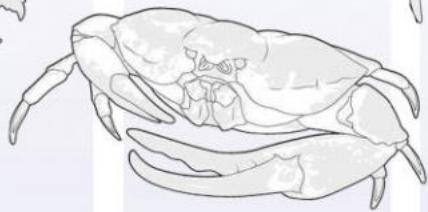
be present in most cells in the body. Ordinary DNA tests won't normally detect this because they only examine a short section of the DNA, in a region known to be highly variable between individuals. But if the entire genome were sequenced, these differences would show up. In France a case of multiple rape, in which identical twin brothers were both suspects, was solved in this way in 2012.

Your DNA also gets modified by epigenetic mechanisms such as DNA methylation. This changes the chemical structure of the DNA and affects how active certain genes are, based on diet and other lifestyle differences. So identical twins that have lived different lifestyles could also be genetically distinguished in this way. **LW**



4. Tasmanian giant freshwater crayfish

Length: 80cm
Distribution: Rivers and streams in Tasmania



4. Tasmanian monster crab

Leg span: 80cm
Distribution: Oceans off southern Australia



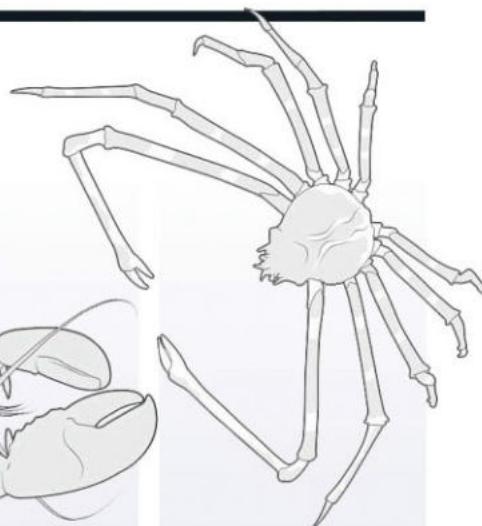
3. Coconut crab

Leg span: 1m
Distribution: Indian Ocean and Central Pacific Ocean



2. American lobster

Length: 1m
Distribution: Atlantic Ocean around North America



1. Japanese spider crab

Leg span: 4m
Distribution: Pacific Ocean around southern Japan

What is the bug bounty programme?

LEN SMITH, KING'S LYNN

Some hackers love to break into computer systems to see what's 'under the hood'. It's a big problem, so security has to constantly be improved to prevent intrusion.

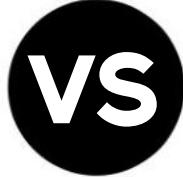
Several years ago, one company called Netscape Communications had a smart idea. They invited the hackers to try to break into the early versions of their software, and paid them if any issues or vulnerabilities were found. This became known as the bug bounty programme, and it is used by many software companies today to help improve their products. **PB**



HEAD TO HEAD



FUKUSHIMA



CHERNOBYL

800	RADIATION RELEASED (petabecquerels*)	5,200
3,200	SPREAD OF RADIATION (km ²)	200,000
300,000	POPULATION EVACUATED	335,000
0	PREDICTED CANCER DEATHS	up to 57,000
£70bn	COST	£185m

Only two events have ever reached the maximum level 7 on the International Nuclear Event Scale: the Chernobyl meltdown in 1986 and the Fukushima disaster of 2011. But the causes and effects of the two were

quite different. Chernobyl released more radioactive material but cost much less to clean up, principally because almost no compensation was paid to the people affected by the fallout. **LV**

*One becquerel is a unit of radiation equivalent to one nucleus decay per second. One petabecquerel is 10^{15} becquerels.

Why does cold water take your breath away?

SHAMOY PHILLIPS-JONES, BRISTOL

It's called the cold shock response. When the cold receptors in your skin are all suddenly stimulated they cause an involuntary gasp and, for about a minute after that, hyperventilation. If you fall into chilly water, the cold shock response will kill you long before hypothermia does. Either that first gasping breath will fill your lungs with water (drowning you instantly), or the hyperventilation will make swimming almost impossible. In the UK, 67 per cent of drowning victims are strong swimmers, and over half of those are within 3m of the shore or the side of their boat when they drown. **LV**

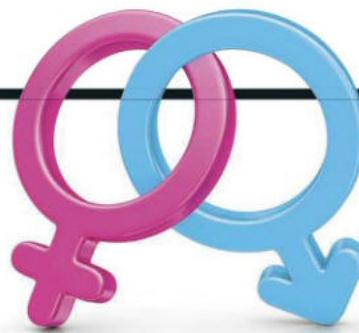
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In Denmark, many people take part in 'winter bathing', plunging into the freezing sea to experience the water's invigorating effects

PHOTOS: GETTY X3/STOCK NASH



Why are there two sexes?

SOPHIA WAN, CROYDON

Biologically speaking, the most important difference between the sexes is that females produce eggs that are much larger than the sperm of the male. Large eggs are an advantage because they provide more resources for the developing zygote. But making your eggs large means that you can't produce so many of them, so another valid evolutionary strategy is to make lots of small, cheap sperm. Both of these strategies seem to be more effective than the compromise of producing a moderate number of middle-sized gametes, so evolution has gradually driven eggs and sperm in different directions. Once they've evolved to have different gametes, the sexes are also driven to evolve other differences. For males to be promiscuous, and females to be choosy, for example. **LW**



Why doesn't Earth's atmosphere vanish into the vacuum of space?

KAVISH PRIOLKAR, GOA, INDIA

While we can't see them, the gas and vapour molecules making up the atmosphere all have mass, and as such all feel the gravitational pull of the Earth. They could still escape if they had enough energy – for example, if the Earth was closer to the Sun, and thus hotter. Fortunately, however, our planet has just the right mass and distance from the Sun to avoid that. **RM**



Could Earth capture an asteroid?

MARK FOSTER, LEICESTER

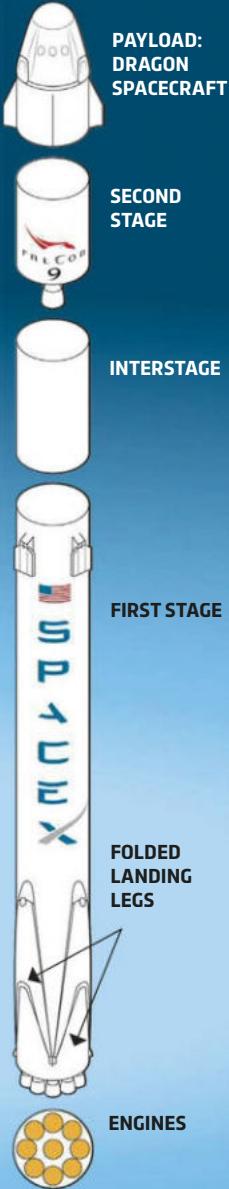
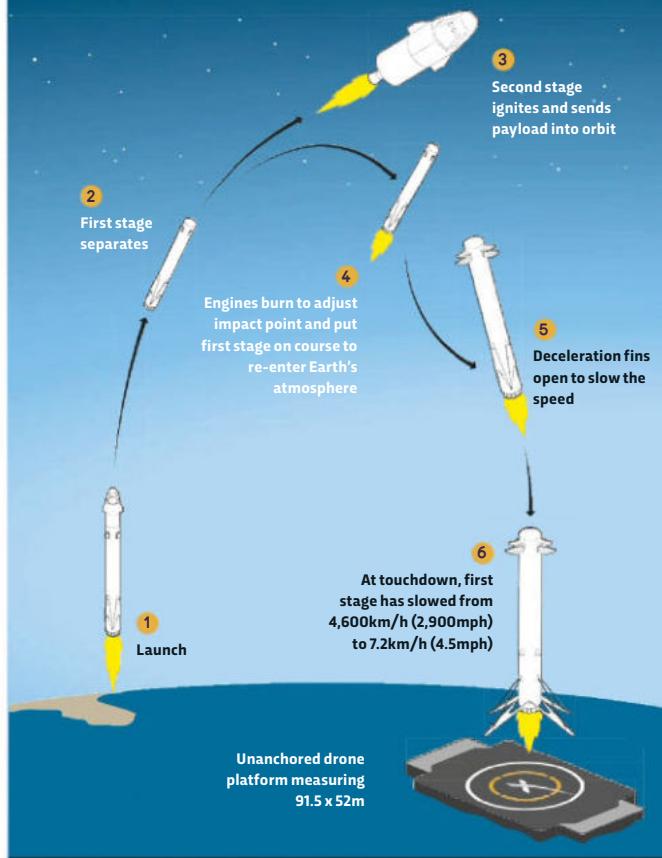
It is certainly possible but highly unlikely. Typically, asteroids are travelling far too fast for Earth's gravity to make much of an impact on their trajectories. They normally have more than enough energy to escape Earth's influence even if they approach very close. However, if they are of the right mass, are travelling at just the right speed, and manage to miss our planet by just the right amount, they could end up in a stable orbit around Earth. This capture process was probably how Mars got its two small moons, Phobos and Deimos. AG

HOW IT WORKS

THE FALCON 9

SpaceX's Falcon 9 is the world's first reusable rocket and is designed to deliver the Dragon spacecraft to the ISS. In early April, SpaceX successfully launched the Dragon into

space aboard a Falcon 9, then landed the rocket on a floating platform in the ocean. The innovative technology could slash the costs of space travel and improve reliability.



WHAT CONNECTS...

...GUN SIGHTS AND WOUND SUTURING?

1.



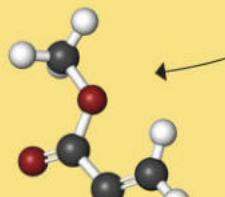
In 1942 Dr Harry Coover was looking for clear plastics that could be used for lightweight gun sights in WWII. One of the chemical groups he tested was the cyanoacrylates.

2.



Coover discarded them as a suitable material because cyanoacrylates bond instantly to almost anything. But in 1958 the company Eastman Kodak took advantage of this and sold it as Eastman #910, which was later renamed 'super glue'.

3.



Cyanoacrylates are liquid at room temperature. But the presence of even a tiny amount of moisture causes the cyanoacrylate molecules to link rapidly into a long sticky chain.

4.



In 1966, field medics in the Vietnam War used a cyanoacrylate spray to temporarily seal wounds. Today, medical grade super glue is often used to repair small cuts.

WHAT IS THIS?

Floating fern

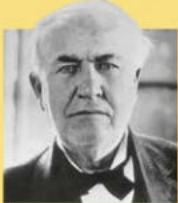
This image of the water fern *Salvinia natans* was taken using an electron microscope.

The tiny structures shown here, which look a bit like egg beaters, are hairs that blanket the top surface of the leaves. The hairs repel water, while the brown areas at the tips attract it. Nanotechnologists think that materials inspired by the plant could be used on the hulls of ships to reduce drag.

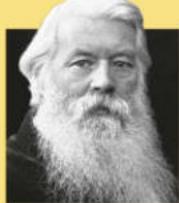
WHO REALLY INVENTED?

THE LIGHT BULB

DAVID EDWARDS, VIA EMAIL



THOMAS EDISON



JOSEPH SWAN

The basic idea of using electricity to create light was first investigated over 200 years ago by the English chemist Humphrey Davy. He showed that when electric current flowed through wires, their resistance caused them to heat up to the point where they gave out light. But he also identified the key problem to creating the first practical 'incandescent light': finding a cheap material that both burned brightly, and lasted for many hours.

US inventor Thomas Edison is often credited with creating the solution in 1879: the carbon filament light bulb. Yet the British chemist Warren de La Rue had solved the scientific challenges nearly 40 years earlier. He used thin – and thus high-resistance – filaments to achieve the brightness, and delayed burnout by making them from high-melting-point metal sealed in a vacuum. His choice of pricey platinum for the filament and the difficulties of achieving a good vacuum made the result uneconomic, however. In 1878, another British

chemist, Joseph Swan, publicly demonstrated the first light based on commercially-viable carbon, but his use of relatively thick filaments still led to rapid burnout.

Edison's combination of thin carbon filament design with better vacuums made him the first to solve both the scientific and commercial challenges of light bulb design.



Bagheera kiplingi is agile with fantastic eyesight – these skills help it dodge the ants that protect its veggie food source

Are there any vegetarian spiders?

LINDSAY BAILY, PETERBOROUGH

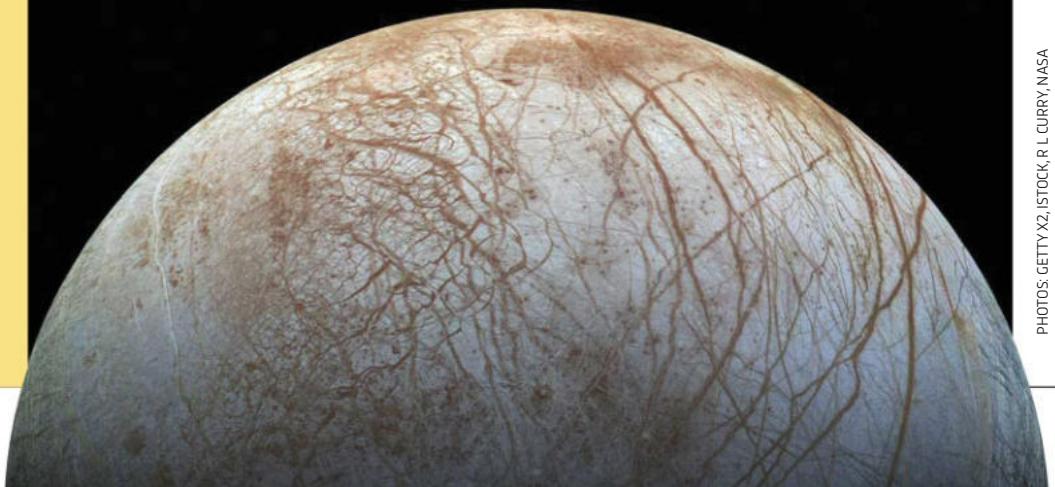
Just one. Out of around 40,000 spider species, *Bagheera kiplingi* is the only spider known to have a herbivorous diet. It lives in Mexico and Costa Rica, and feeds mostly on protein nodules of the acacia tree. But even this spider sometimes eats ant larvae, so perhaps it is closer to the sort of vegetarian that doesn't count prawns! **LW**

Why doesn't Europa have any impact craters?

PEARL SERRUYA, GIBRALTAR

Europa is one of the smoothest objects in the Solar System. Although there are many surface features, including craters, these are few and far between. It is believed that Europa's surface is a series of brittle tectonic ice plates moving on top of a warmer layer of convecting ice. Beneath that is probably a subterranean

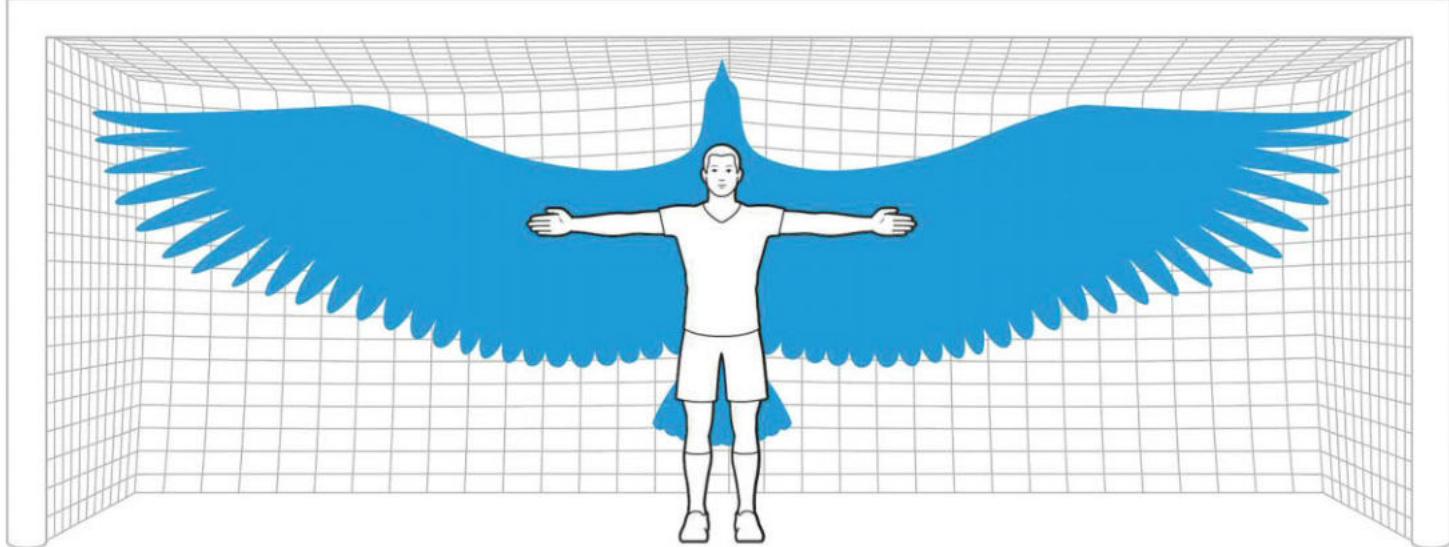
ocean of water. Recent observations have shown these icy tectonic plates moving about, creating ice plumes and 'cryolavas' in a mechanism akin to volcanism on Earth. This constant recycling of the surface material means that craters and other features don't survive for very long. **AG**



If humans had wings, what would their wingspan be?

SELINA PHILLIPS, BRISTOL

The extinct bird *Argentavis magnificens* weighed about as much as an adult human and it had a wingspan of 7m – four times the average human arm span. This bird had lots of other adaptations to allow it to fly though, including the muscles to support these wings and flap them. Hang gliders, which allow humans to ‘fly’, are 9-10m across. **LV**



Why does heat have a shadow?

TESS FOY, STAFFORD

Thermal energy – the physicist’s term for heat – comes in various forms, including infrared radiation, which is part of the electromagnetic spectrum, like visible light. As such, this form of heat can be blocked by objects, creating a shadow. But the other forms of heat can still get to us via, for example, the motion of warm air known as convection. **RM**

What causes recurring nightmares?

LOUISE CARR, EXETER

Approximately 2 to 5 per cent of the population suffers from recurring nightmares, and often the reason is that they have survived some kind of life-threatening situation, such as a car accident or a violent attack. Indeed, one study estimated that between 50 to 70 per cent of patients with post-traumatic stress disorder (PTSD) experience chronic nightmares. Other psychiatric conditions associated with an increased risk of experiencing frequent nightmares include schizophrenia, anxiety, and alcohol and drug abuse. Among people without a psychiatric diagnosis, a dream diary study from 2003 found that nightmares were experienced more often at times of stress. **CJ**



NEXT ISSUE: Space Q&A special

Can you burp in space?

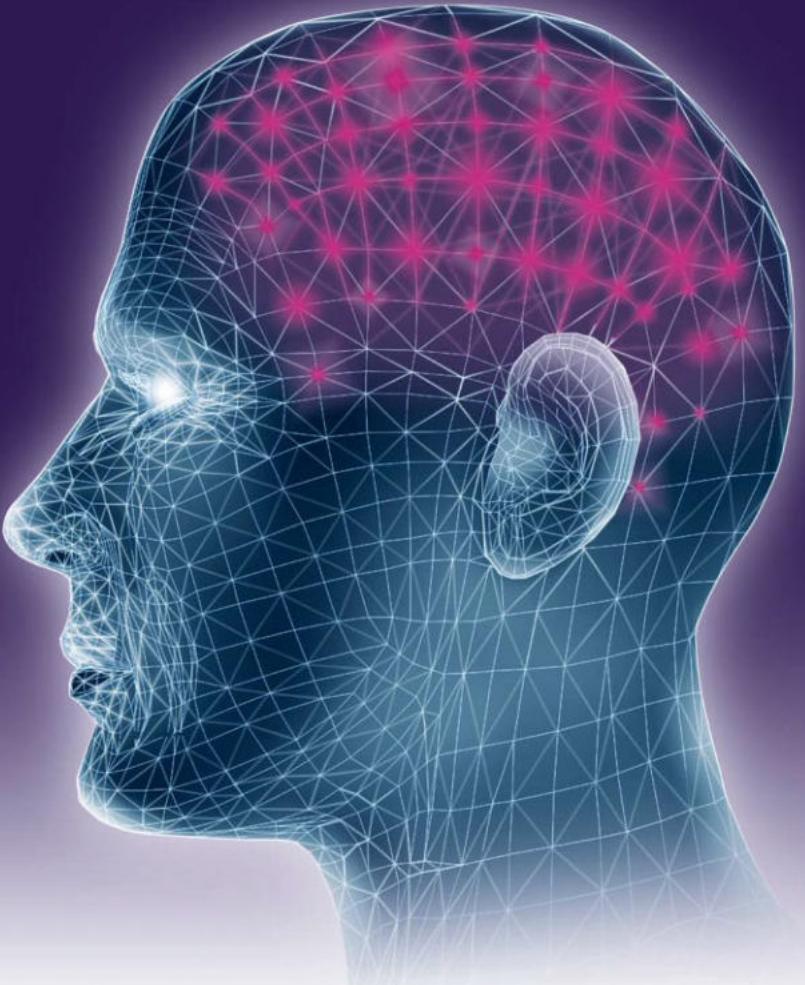
What does space smell like?

Why do stars twinkle?

And much more!

Email your questions to questions@sciencefocus.com or submit online at sciencefocus.com/qanda

Feed your mind

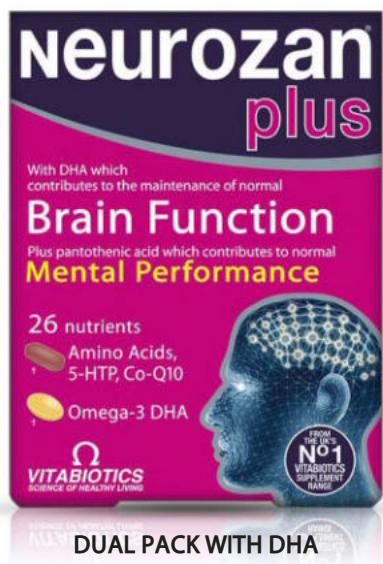


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*Nielsen GB ScanTrack Total Coverage Value Sales 52 w/e 25th April 2015.



VITABIOTICS
SCIENCE OF HEALTHY LIVING



HELEN CZERSKI... RAINDROPS AND WIND SPEED

"I WOULD LOVE TO BE ABLE TO STAND IN A STORM AND WATCH THE RAINDROPS IN SLOW MOTION"

R

ainstorms are lovely. I like the drama and the feeling of release as the sky washes itself clean. Even though I'm usually happiest outdoors, in the middle of the action, the best place to enjoy a rainstorm is often on the warm, dry side of a pane of glass.

A couple of weeks ago I was watching a particularly enthusiastic storm batter the windows, and I noticed that the raindrop streaks on one window facing the wind were vertical – drops hit and then ran straight downwards. But my living room is on the corner of the building, and the drops hitting the window on the other wall were at a considerable angle, obviously being blown sideways across the glass. It was striking that the drop splashes all had very similar angles. Parked there on the sofa, watching it all, I wondered whether I could measure the wind speed from the angle of the raindrop splash. So I had a go.

The angle of the splash depends on how the drop's downward speed compares to its sideways speed. Even though raindrops are being blown about by the wind, they're still falling downwards through the air. So the first question is: how fast does a raindrop fall?

I would love to be able to stand in a storm and watch the raindrops in slow motion, because there's so much going on. In the simplest case, each drop will fall at its terminal velocity. This is the speed at which the force needed to shove air out of the way is equal to the gravitational pull on the drop. The bigger the drop, the faster its terminal velocity. But in one rainstorm, there are drops of lots of different sizes, so they're all falling at different speeds. In heavier rain, the raindrops are generally bigger. In the heavy rain that I was looking at, most raindrops were probably between 1.5 and 4mm in diameter – twice as wide as those in very light rain. That gives them terminal velocities between 16 and 32km/h. So I picked a value in the middle and assumed that the raindrops I was looking at were travelling downwards at about 24km/h.

Then I had to look at the angle. The wind was travelling from right to left as I looked at the window, and the drops were being blown sideways very strongly – the splashes were in the direction of about 8 o'clock on a clock face, or about 60 degrees from vertical. To get

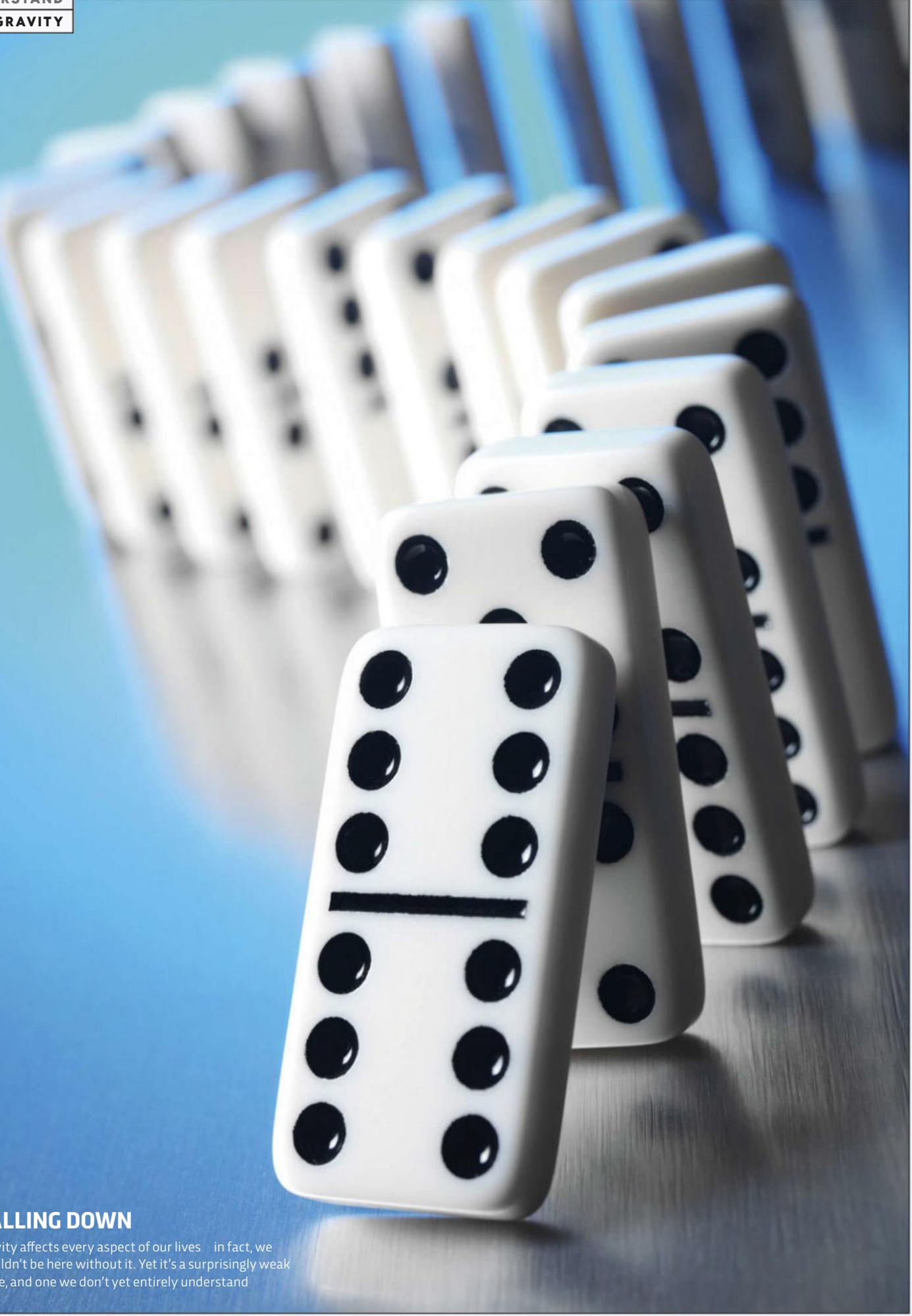


an angle like that, the drop has to be blown sideways almost twice as fast as it's falling downwards, giving me a sideways wind speed of 48km/h. To get the direction of 7 o'clock, you only need the sideways speed to be just over half of the downward speed. If I'd seen that, the implied wind speed would have been 14.5km/h. It takes a surprisingly large additional wind speed to get from 7 o'clock to 8 o'clock! A quick check on the Met Office website suggested that the actual wind speeds outdoors were 40-48km/h, so I was quite pleased with my rough estimate of 48km/h.

Of course, there are a few complications here – I didn't know the exact raindrop size, and turbulence around the building could have given the wind a slight upward or downward component. And I was lucky that one window was oriented exactly sideways to the wind. But it was nice to know that I could estimate the ferocity of the storm. And it justified the decision to be inside watching, rather than outside getting drenched! ☺

Dr Helen Czerski is a physicist and BBC science presenter. Her book, *The Storm In A Teacup*, will be out in November.

NEXT ISSUE: SUGAR GLASS



FALLING DOWN

Gravity affects every aspect of our lives – in fact, we wouldn't be here without it. Yet it's a surprisingly weak force, and one we don't yet entirely understand



UNDERSTAND GRAVITY

Everyone knows that what goes up must come down.
But why? Gravity, it turns out, is full of surprises...

WORDS: BRIAN CLEGG

Without gravity, we wouldn't exist. It provides the force that keeps us on the surface of the Earth, and the Earth in orbit around the Sun. It was responsible for the formation of the Solar System in the first place, and it's the gravitational attraction of all the material in the Sun, pulling it tightly together, that makes it possible for nuclear fusion to take place, giving us heat and light. Yet despite its ubiquity, gravity is one of the most mysterious forces in the Universe.

What is gravity?

As one of the four fundamental forces of nature – alongside electromagnetism and the strong and weak nuclear forces – gravity is a hugely influential natural phenomenon. It's a property of matter, of stuff. In a nutshell: all matter is attracted to all other matter. The more matter there is, and the closer objects are to each other, the bigger that attractive force. And unlike electricity and magnetism, which can either repel or attract, gravity always pulls things together.

What was Newton's theory of gravity?

Newton famously stated that he did not have a hypothesis for how gravity worked. Instead, his starting point for describing it in action was the idea that gravity was universal – that the same thing that made an apple fall from a tree kept the Moon in orbit. With this concept, a collection of astronomical data, and some clever thought experiments, Newton was able to show that just three things influence the gravitational attraction between two objects: the mass of each object and the distance between them.

Although he never wrote it out in this form, his theory would show that gravitational attraction follows an inverse square law. The pull of gravity can be calculated by multiplying together the masses of the two objects and then dividing by the square of the distance between them. So the attractive force of gravity goes up as either of the objects' masses increases, or as they get closer together. This simple relationship was enough to

Newton's ideas about gravity dominated science for three centuries

explain almost all of the movement of the Moon and planets, and would be all that NASA needed to calculate a safe trajectory for the Apollo mission to the Moon.

What is the equivalence principle?

The equivalence principle is based on what Albert Einstein described as his "happiest thought". This was that "if a person falls freely, he will not feel his own weight". In other





In 2004/5, NASA's Gravity Probe B mission helped to confirm Einstein's theories

• words, acceleration and gravity are exactly equivalent and indistinguishable.

We see this happening on the International Space Station. The pull of gravity at the station's orbital distance from Earth is around 90 per cent of that on the surface. The reason people float about up there is because they are constantly falling towards our planet. We might expect them to crash into the Earth's surface, but they are also moving sideways at just the right speed to keep missing – that's what being in orbit involves.

The equivalence principle shows that accelerating, as happens when a person falls, cancels out their weight. Einstein made the leap from his happy thought to suggest that acceleration and gravity are, in effect, the same thing. And this inspired his General Theory of Relativity, which both predicts the force of gravity and explains how it works.

What were Einstein's ideas about gravity?

From his equivalence principle, Einstein was able to show that bodies with mass – anything from an atom to a star – warped space and time. And it was this warping that explained something Newton had never been able to show: why gravity was capable of operating at a distance. Like a basketball on a trampoline surrounded by marbles, more massive objects produce larger warps in the fabric of space-time, drawing in nearby objects and causing them to move in curved trajectories. But even smaller bodies have an effect – each of us exerts a tiny gravitational force on the objects around us. Because he was taking a very different approach from Newton, Einstein had to use a different kind of mathematics,

one that he himself initially knew little about: the mathematics of curved space. And he had to take into account various secondary effects which Newton had no reason to suspect existed, such as the surprising discovery that gravity has an effect on itself.

Einstein's equations of General Relativity do everything Newton's equation does, predicting the size of the attractive force between two bodies, but because they describe the way that anything with mass warps space and time, they can do much more.

Did Einstein prove Newton wrong?

Absolutely not. Newton's work was descriptive: he fitted a simple mathematical equation to what was observed. His mathematics tell us nothing about how gravity works, but as a description of the behaviour of everyday things, it worked very well – and still does.

What Einstein did was to help us understand what *causes* the force we describe as gravity. He was able to show that there are certain circumstances, typically where the pull of gravity gets very strong, where Newton's equation is not a good enough approximation. In these cases, we have to bring in Einstein to get a more accurate figure. And Einstein also comes in useful to make predictions that wouldn't even be envisaged under the basic workings of Newton's physics.

What proof do we have for Einstein's theory?

There is a huge amount of evidence for General Relativity. Before Einstein came up with his theory, astronomers had struggled to explain an aspect of Mercury's orbit called its precession, where its point of

JARGON BUSTER

Antimatter

The equivalent of matter, but with some characteristics such as charge reversed. Antimatter has only ever been made in very small quantities, so we don't yet know how it's affected by gravity.



Inverse square law

The gravitational force follows an inverse square law, which means gravity is inversely proportional to the square of the distance between two objects. As they get further apart, the gravitational force rapidly diminishes.



Matter

A description of the amount of matter ('stuff') in an object, mass tells us how much gravitational force it will experience. Mass does not change depending on where the object is.



Precession

The orbit of a planet does not follow exactly the same path every time, but undergoes precession, shifting its position around its host star. The precession of Mercury's orbit could not be explained by Newton's theory.



Space-time

In Einstein's Special Theory of Relativity, space and time are pulled together into a single concept: space-time. Objects with mass warp space-time, influencing time as well as space.



Weight

Confusingly, we often use the units of mass for weight, but it's totally different. Weight is the force an object experiences due to gravity, so is different, say, on the Earth than it is in space.

HOW TO DETECT GRAVITATIONAL WAVES

Since 2002, the Laser Interferometer Gravitational-Wave Observatory has been hunting for direct evidence of gravitational waves

CATCHING A WAVE

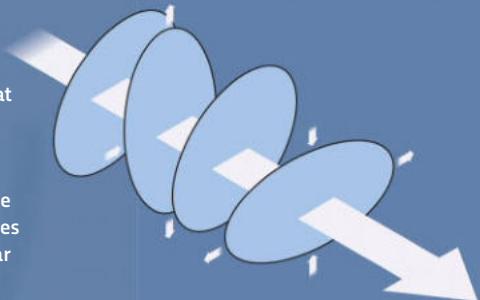
Einstein's General Theory of Relativity tells us that if two massive objects, such as two black holes, are bound together by gravity, they should create ripples in the fabric of space-time. These ripples are called gravitational waves.



SPACE

GYMNASICS

As a wave travelling at the speed of light passes through space-time, it first stretches space in one direction and squeezes it in the perpendicular plane, then reverses the process.



THE LIGO EXPERIMENT

There are two LIGO observatories, which are located 3,002km apart. Each LIGO observatory consists of a laser source, two detector arms, each with a mirror at the end, and a light detector. The laser shines onto a beam splitter and is sent down the detector arms, which each measure precisely 4km in length. If light waves fall out of sync due to being affected by gravitational waves, then the resulting 'spillage' of light will be picked up by the light detector.

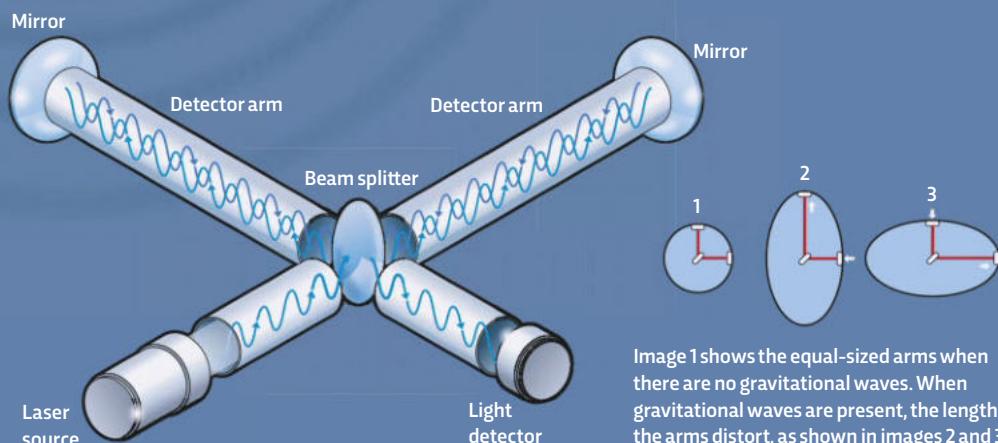


Image 1 shows the equal-sized arms when there are no gravitational waves. When gravitational waves are present, the lengths of the arms distort, as shown in images 2 and 3.

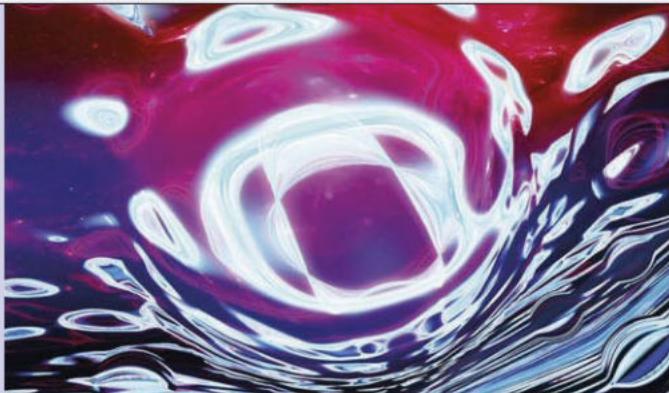
WHAT WE STILL DON'T KNOW

1 WHY GRAVITY IS SO WEAK

Because gravity plays such a major part in our daily lives, it's hard to appreciate just how weak it is. When you pick up a pin with a small magnet, for instance, the magnet's electromagnetic force is overcoming the gravitational attraction of the entire planet. Some theories suggest that this weakness is because gravity 'leaks' out into different dimensions, but we are unlikely to get a testable explanation without first devising a quantum theory of gravity.

2 WHEN WE'LL PRODUCE A QUANTUM THEORY OF GRAVITY

Almost any physicist will tell you it could be very soon, but they've been saying that for 40 years. As yet, the first main contender – string theory – and its various rivals have failed to be developed into full-blown, testable theories. And that's with hundreds of people working on them. It still seems likely we will succeed, but it may need a whole new theory to be developed before the problem can be cracked.



String theory tries to unify the four fundamental forces: gravity, electromagnetism, the strong nuclear force and the weak nuclear force

3 WHETHER WE CAN PRODUCE ENOUGH GRAVITY TO LIVE IN SPACE

Living things deteriorate without gravity. The equivalence principle tells us we can make artificial gravity by accelerating, but the only way to do so constantly without using too much fuel is to spin, and if you spin too small a craft the occupants get dizzy. Experiments with artificial gravity have been underway since a 1966 Gemini mission, but we don't yet have a realistic solution.

**In one tweet...**

To paraphrase physicist John Wheeler: matter tells space-time how to curve and space-time tells matter how to move – that's #gravity

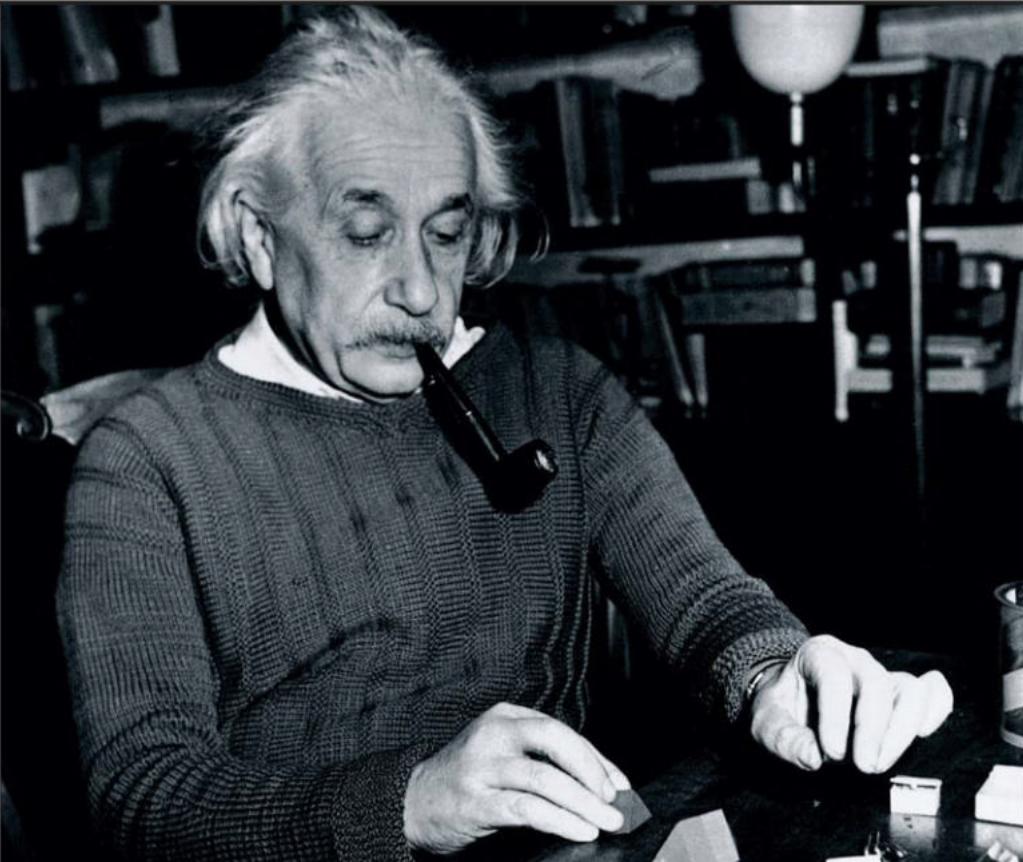
- closest approach to the Sun gradually changes position. Newton's equations couldn't explain the full effect, but Einstein's work did.

What's more, the idea that gravity was caused by a warp in space and time was also testable, because it meant that (for instance) light passing close to a very massive body should travel in a curved line, passing through the warped space that the body creates. This was first observed with light passing close to the Sun during a total eclipse in 1919, and has since been seen when distant galaxies act like lenses, bending the path of light behind them.

Another of the predictions of Einstein's equations is that being near a massive body slows time down: this is why we need to correct the signal from the GPS satellites that give us sat-nav. Equally, an experiment called Gravity Probe B has demonstrated that a rotating massive body drags space-time around with it like a rotating spoon in honey, just as Einstein had foreseen.

What does gravity have to do with black holes and the nature of the Universe?

The predictions of Einstein's theory are usually the result of solving simplified versions of his equations. One of the earliest described a compressed mass where all the matter was in a single point – a 'gravitational singularity'. Later, it was realised that some ageing stars would be unable to resist the pull of gravity and should collapse in on themselves to form such a point, creating a black hole. The gravity in a black hole is so strong that not even light can escape, and although we've never seen one, indirect observations confirm that they do exist.



Einstein's General Theory built on Newton's work but still doesn't give us the whole story

Similarly, General Relativity predicted that the very fabric of the Universe could expand and contract. Combined with observations, this has become the basis for our best theory on how the Universe developed: the Big Bang model. It is also General Relativity that could shed light on dark energy – the mysterious phenomenon that seems to be accelerating the expansion of the Universe.

What are gravitational waves?

A body with mass warps space and time, so if that body accelerates through space it should cause ripples in the space-time around it. These ripples are called gravitational waves and move outwards, rather like the way that accelerating electrons up and down an aerial generates the electromagnetic waves of radio and television.

Gravitational waves, which Einstein predicted shortly after developing his General Theory of Relativity, should be produced all the time from vast numbers of sources. However, gravity is an extremely weak force, which means that these waves are extremely difficult to detect. When the LIGO experiment observed gravitational waves for the first time in September 2015, it was the result of a massive disturbance in space-time caused by two merging black holes. LIGO's detectors are so sensitive that any vibrations have to be eliminated, from passing cars to distant waves crashing on a beach. Gravitational waves are important not because they 'prove Einstein's theory' – we already have plenty of evidence for that – but because they give us a new way to study the

EXPLAIN IT TO A FRIEND

1 THERE'S NO ESCAPING IT

Matter has a fundamental property that means pieces of it are attracted towards each other. We call this gravity, and it's everywhere. Gravity gets stronger as the amount of matter increases, and as the distance between the pieces decreases – as Newton first described over 300 years ago.

2 A TALE OF SPACE AND TIME

Although Newton's formula for gravity will usually describe what happens, it isn't always correct, and Newton didn't describe how gravity works. Einstein built on Newton's work, realising that matter warps space and time. Objects moving in a straight line curve – so planets orbit the Sun – and stationary objects fall towards massive bodies.

3 RELATIVITY RULES

Einstein's General Theory of Relativity predicted all kinds of phenomena, from black holes to waves in space-time. These gravitational waves have recently been detected, giving us a new way to study the Universe. But General Relativity still doesn't fit with the other forces of nature: we need a quantum theory of gravity to complete the picture.

The first proof that Einstein was right came in the form of a 1919 solar eclipse



Very massive objects such as galaxies warp space-time itself

Universe, looking back to its earliest years where not even light can reach.

Is Einstein's theory the whole of the picture?

Almost certainly not. General Relativity is extremely effective and doesn't put a foot wrong when it comes to making predictions about the behaviour of everyday objects, but there are a few circumstances – notably in the heart of a black hole, or in describing the Universe before the Big Bang – where the theory breaks down.

The physics of the very small is described with impressive accuracy by quantum theory, but General Relativity and quantum theory are incompatible. All the other forces of nature are 'quantised' – coming in chunks, rather than continuously variable amounts. The assumption is that it should be possible to develop a quantum theory of gravity that would bring it in line with the other forces and still produce the same results as Einstein's theory for larger objects. As yet, the best attempts are string theory/M-theory and loop quantum gravity, but neither one has produced any usable predictions yet.

Could gravity be caused by a subatomic particle?

It's very likely, and it already has a name: the graviton. One way that quantum theory represents the transmission of a force like electromagnetism is as a flow of carrier particles called 'bosons'. In the case of electromagnetism, the particle is the photon. Each particle is a 'quantum' – a chunk – of the quantised phenomenon.

So if gravity is a quantum effect, we assume that there will be a graviton as its carrier. However, don't expect one to

turn up at the Large Hadron Collider any time soon. A graviton is so unlikely to interact with another particle in a detectable way that there is currently no realistically conceivable experiment that could spot one.

Is there such a thing as antigravity?

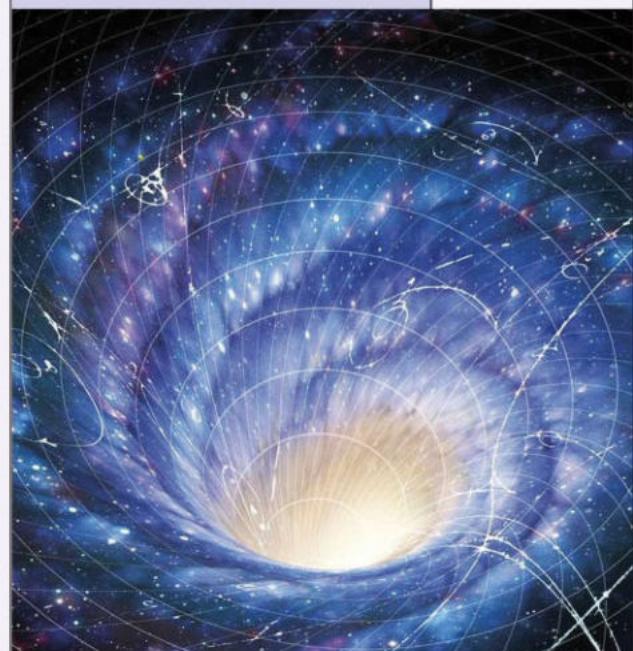
Not that we know of. Unlike electromagnetism, gravity is a one-way effect – it just attracts. We can offset gravity with other forces; you do that every time you pick something up. It looks particularly impressive when the opposing force is invisible electromagnetism – such as when something floats over a magnet – but it's not antigravity.

We don't know any way to shield against gravity, either: it passes through everything. If we could stop gravity in its tracks, we could make a perpetual motion machine and generate free energy. Paint the same side of each paddle of a waterwheel with the barrier substance. The paddles on one side of the wheel will have their bare sides facing the Earth, so will feel its gravitational pull, while the paddles on the other side will be screened from gravity. So just one side of the wheel will be pulled downwards, and it will turn forever.

The one small chance of discovering antigravity is that antimatter may be gravitationally repelled by ordinary matter. Scientists at CERN will soon have enough antimatter to test this out, but most physicists think it will behave just like the normal stuff. ☺

Brian Clegg is a prolific science writer. His most recent book is *30-Second Physics* (£14.99, Ivy Press).

NEXT MONTH: HOW DO WE KNOW HOW ANIMALS PERCEIVE THE WORLD?



OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

JUNE 2016

EDITED BY JAMES LLOYD



The orchid cuckoo bee is just one of the insects you can marvel at as part of the *Microsculpture* exhibition

PHOTO: LEVON BLISS/OXFORD MUSEUM OF NATURAL HISTORY



01 INSPECT AN INSECT

MICROSCULPTURE

OXFORD UNIVERSITY MUSEUM
OF NATURAL HISTORY,
27 MAY – 30 OCTOBER 2016,
FREE ADMISSION.

They're the most diverse group of animals on the planet, but for the most part, insects go about their job unnoticed. These incredible images, featured in a new exhibition at the Oxford University Museum of Natural History, give them their dues. Each portrait was created from around 8,000 individual photographs, seamlessly stitched together by British photographer Levon Biss to create breathtakingly detailed, large-format prints.



There's plenty to keep children and adults amused at the Cheltenham Science Festival

02

GET IN THE MOOD FOR FESTIVAL SEASON

The days are getting longer and the cider is in the cooler. Yes, festival season is here – that time of the year when many of us like nothing more than to stand in a muddy field with thousands of others clutching a plastic cup of a dubious-smelling drink.

This June, there are two festivals catering for science lovers to pop in your diary. Cheltenham Science Festival returns for another year, while Warwickshire hosts Also Festival, described as 'TED Talks in a field'. Here are some of our highlights.

CHELTENHAM SCIENCE FESTIVAL

7-12 JUNE, VARIOUS VENUES IN CHELTENHAM
CHELTENHAMFESTIVALS.COM/SCIENCE

LIVING WITH MENTAL ILLNESS

EPARABOLA ARTS CENTRE,
THURS 9 JUNE, 3PM-4PM, £7
One morning in January 2008, Jonny Benjamin was about to jump from Waterloo Bridge. He was talked out of suicide by a passing stranger – Neil Laybourn. Here, the two men discuss mental health and the stigma that still surrounds it.

CAPTURING THE SUN

EXPERIMENT, SAT 11 JUNE, VARIOUS TIMES, £8
Using six-month-exposure pinhole cameras made from old drinks cans, Nick Sayers creates beautiful, otherworldly images of the Sun's path across the sky. In these hands-on workshops, he shows you how to build your own Sun-capturing camera.

SCIENCE VARIETY NIGHT: AN EVENING OF UNNECESSARY DETAIL

EDF ENERGY ARENA,
SAT 11 JUNE, 8PM-9.30PM, £15
If you like your laughs with a dose of maths, here's a fine way to spend your Saturday evening. Join number-boffins Hannah Fry and Matt Parker as they host an evening of music, comedy, words and science.

ALSO FESTIVAL

17-19 JUNE, COMPTON VERNEY, WARWICKSHIRE
ALSO-FESTIVAL.COM

THE SCIENCE OF SWEARING

What gives swear words the power to shock and offend? Where did the words come from? And why do we swear in the first place? Comedian Alexis Dubus investigates the psychology of cursing.

MUSICAL MEMORY

We all have songs that summon up special moments in our lives. Neuropsychologist Catherine Loveday discusses why music is so important to our memories, and what it is about a good song that makes us want to dance.

THE PERFUMED LAKE

All festivalled out? Plunge into the site's lake for a 'perfumed swim experience' to rekindle the senses, complete with a concert pianist playing Handel's *Water Music* from the middle of the lake. So decadent it'd make Liberace blush.



03

CELEBRATE THE TIDE

In his new book, HUGH ALDERSEY-WILLIAMS sheds light on one of nature's most powerful phenomena – the ocean's tides. He speaks to JAMES LLOYD

TIDE: THE SCIENCE AND LORE OF THE GREATEST FORCE ON EARTH BY HUGH ALDERSEY-WILLIAMS
IS OUT NOW (£18.99, PENGUIN).

Why did you decide to write a book about the tide?

I live near the coast in Norfolk and I sail, but I felt much more ignorant about the real workings of the tide than I should. I think the tide plays an underappreciated role in our lives – we only tend to think about it when we're sitting on the beach. I wanted to explain the science of the tide, but also the moments where it was pivotal in history and culture – where it determined the course of battles and inspired poets and artists.

Who was the most important scientist in helping us understand the tide?

A lot of people made individual steps, from the Venerable Bede in the 8th Century to Galileo, Newton and Laplace. Newton is possibly the most important figure here, as he was the first to explain that the tides are caused by the combined gravitational pull of the Sun and Moon. We now know that lots of other factors play a role, too, such as irregularities in the Earth and Moon's orbits, the shape of the Earth, the profile of the coast and ocean floor, and even the presence of ice shelves. It's knowing all these factors that allows us to calculate the tides at any time in the future or past.

What was the most memorable experience you had while writing your book?

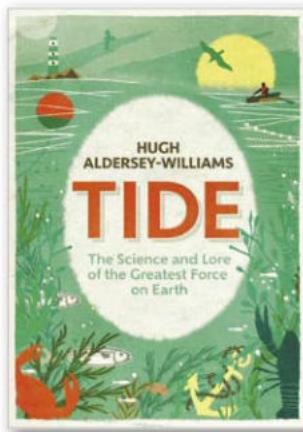
It was going to see the site of the 'original' maelstrom in northern Norway – the giant vortex of water that Jules Verne and Edgar Allan Poe wrote about. In some senses it was an anticlimax, because those accounts had built up in its

terror and scale – you don't see a big, sucking whirlpool. But there is a very slow, majestic circular movement, probably a couple of hundred metres in diameter. We whizzed straight over the top of it in our powerboat, but you wouldn't want to be swimming.

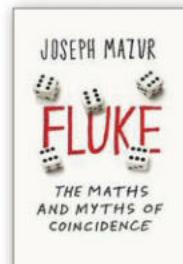
What role does the tide play in the natural world?

The intertidal zone [the area between high and low tide] is constantly changing and being replenished by the sea. It's like a supermarket – everyone goes there because food keeps arriving. It offers protection and food in alternation, and that's what many species need.

Our own lives are so ruled by the cycle of light and dark that it can be hard to believe that there are life forms that are governed by the tide. There are fish in California called grunion that lay their eggs on the beach during high spring tide, timed so that the eggs hatch at exactly the time of the next spring tide some days later. It's a very beautiful, neat means of reproducing.

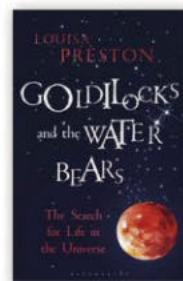


ALSO OUT THIS MONTH



FLUKE: THE MATHS AND MYTHS OF COINCIDENCE BY JOSEPH MAZUR
Out 2 June (£12.99, Oneworld)

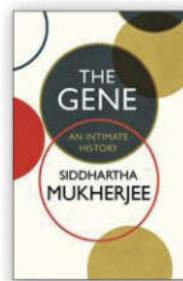
Have you ever bumped into an old school friend on holiday? This mathematical take on coincidence reveals that even the unlikeliest of events can come true. Just ask the woman who won the lottery four times...



GOLDILOCKS AND THE WATER BEARS BY LOUISA PRESTON
Out 16 June (£16.99, Bloomsbury Sigma)

Astrobiologist

Louisa Preston looks at the latest thinking around extraterrestrial life, explaining how earthly 'extremophiles' like the water bear are directing our search for life elsewhere in the cosmos.



THE GENE: AN INTIMATE HISTORY BY SIDDHARTHA MUKHERJEE
Out 2 June (£25, Bodley Head)

A history of genetics with a personal touch. As well as detailing the major breakthroughs, from Mendel and Darwin to Watson and Crick, Mukherjee weaves in the story of his own family's recurrent struggles with mental illness.

04 FIGURE OUT BIG DATA

BIG DATA: DOES SIZE MATTER?
BY TIMANDRA HARKNESS

IS OUT 2 JUNE (£14.99,
BLOOMSBURY SIGMA).

We're living through an information explosion and 'big data' has become one of the key phrases of the 21st Century. TIMANDRA HARKNESS, author of *Big Data: Does Size Matter?*, explains it all

YOU'RE ALREADY USING IT. YOU JUST DIDN'T KNOW THAT'S WHAT IT'S CALLED

Got an app that reads your emails and tells you when to leave for the airport? Uploading your run to an online training programme? Congratulations, you're using artificial intelligence to combine different types of data and tell you something new. Big data is much more than just 'lots of information'. It's everywhere you look, from aircraft engines to online ads.



IT'S CHANGING THE FACE OF SCIENCE

More important than sheer volume of data is the ability to combine different types of information: brain scans, medical records and air quality reports, for example. From astronomy to drug development, powerful computers can spot patterns and alert researchers to hypotheses to investigate.

IT'S PREDICTING YOUR FUTURE

How do supermarkets know what food to stock, or hospitals how many doctors they'll need? It's by combining sources as diverse as weather forecasts and tweets about your social life, and letting computer models tell them what we'll do before we even know ourselves. Now courts are using algorithms to predict which criminals will reoffend, and who should get parole.

IT ALREADY KNOWS EVERYTHING ABOUT YOU

Your smart meter knows how long you spend in the shower. Your health app knows when your heart beats a little faster. By putting together a dozen innocuous bits of info, anyone can get a multidimensional picture of your life.

IT'S WINNING ELECTIONS

Remember all the polls that said the 2015 UK general election would be too close to call? And then the Conservatives won an overall majority? They used data to decide exactly which voters to target, and how best to get their votes. Today's elections are won and lost, not on the doorsteps, but on the databases.



05 EXPLORE ANOTHER UNIVERSE

You step out of your spacecraft onto the surface of an untrodden planet. Strange creatures lumber past – new species unknown to science. You've made history, and all without leaving your sofa.

No Man's Sky will be perhaps the most ambitious video game ever made. Players explore, trade and fight in an open universe that's generated by a scientific 'superformula' based on our understanding of planet formation and evolution. Each star is a sun that can be visited, its planets all unique and ripe for exploration. Developers Hello Games estimate that there are over 18 quintillion worlds in the game – so many that 99.9 per cent of them will never be visited. But that won't stop us from trying...

NO MAN'S SKY IS RELEASED ON PLAYSTATION 4 AND MICROSOFT WINDOWS ON 24 JUNE (£39.99, HELLO GAMES).

DON'T MISS

THE HUMAN ZOO

A welcome new series for this show exploring the habits and peculiarities of that most fascinating of species – us. Returns on BBC Radio 4, 14 June at 4pm.

NEXT MONTH



SPACE

Bumper Q&A space special

What does space smell like? Why is there poo on the Moon? Is Martian water safe to drink? We answer all your cosmic conundrums.

Plus:

- ▶ Your complete guide to every spacecraft we've sent into the Solar System
- ▶ The new race to put man back on the Moon
- ▶ Five years after launch, Juno arrives at Jupiter – what could it find?

HEALTH

WHY ARE WE GETTING FATTER?

We're living through an obesity epidemic, with over 60 per cent of UK adults now said to be overweight or obese. We look at the new science that could explain why.



ENGINEERING

THE SKY'S THE LIMIT

Sixty years ago, the architect Frank Lloyd Wright unveiled plans for a mile-high skyscraper. It was never built, but could we build one today?



PHOTOS: GETTY X3

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CHRISTIAN TREFZGER SHARES HIS FAVOURITE SPOTS IN PARIS



Paris is such an international city – you can find people here from every corner of the world. But it still feels very French in terms of its customs and traditions, and as the city itself is quite small (you can get from one side to the other in 45 minutes on the Metro), it feels a bit like a village.

The one drawback of Paris being a small city is that it can sometimes feel quite crowded. To get away from it all, I either like to walk along the **CANAL SAINT-MARTIN** ① with its series of locks, or wander around the city's largest cemetery **PÈRE LACHAISE CEMETERY** ② to admire the interesting gothic architecture.

One of my favourite parks in Paris is the **PARC DE LA VILLETTE** ③ as it's home to the Cité des Sciences et de l'Industrie, which runs loads of science exhibitions, shows and workshops. It also contains Les Jardins Passagers, which has plants from all sorts of ecosystems and an apiary to shelter bees. Being a plant lover, this is a really special place for me. And there's even a cafe in the park that does excellent mint tea and a piece

of homemade cake for a couple of euros. In the summer, the park hosts jazz festivals too.

THE CENTRE POMPIDOU ④ is a real icon of Paris, with its amazing modern architecture. It always hosts really interesting exhibitions. Plus, from the top floor you get a great view over the roofs of the whole city, all the way across to the Eiffel Tower in the distance.

And, of course, there's the Louvre. It's so vast, each time I go I just visit one section. To avoid long queues, go to the entrance called Porte des Lions (not the main entrance in the glass pyramid), as this can easily save you an hour.

Near to the Centre Pompidou is **LA CRÊPERIE BEAUBOURG** ⑤. I always have a salted crêpe called a galette, a sweet crêpe and a glass of cider. One of my favourite bars to hang out at is Rosa Bonheur. The fact that it's in a park makes it really special.

But I also love to have drinks at the **BREWERRY BAR** ⑥, which is close to where I work at the École Normale Supérieure. You can find a selection of beers here from all over the world – I've never tasted the same beer twice! ☺

① CANAL SAINT-MARTIN
A 4.5km long canal that runs through northern Paris.

② PÈRE-LACHAISE CEMETERY
Its most famous residents include Oscar Wilde, Jim Morrison and Chopin.
20th arrondissement

③ PARC DE LA VILLETTE
Home to the Cité des Sciences et de l'Industrie – the largest science museum in Europe.
19th arrondissement
lavillette.com

④ CENTRE POMPIDOU
Iconic building with a vast public library, the Musée National d'Art Moderne, and IRCAM – a centre for music research.
Place Georges Pompidou,
4th arrondissement
centrepompidou.fr/en

⑤ LA CRÊPERIE BEAUBOURG
The place to go for crêpes.
2 Rue Brémiche,
4th arrondissement
creperiebeaubourg.com

⑥ BREWBERRY BAR
Pub that serves a variety of international beers.
18 Rue du Pot-de-Fer,
5th arrondissement
brewberry.fr

Christian Trefzger is a quantum physicist working at the École Normale Supérieure and Institut d'Optique in Paris.



How to Become a Successful Writer!

By Marian Ashcroft

If you've ever fancied being a writer but don't know where to start – here's the answer. For the past twenty-seven years The Writers Bureau has been running a home-study Creative Writing course that teaches ordinary people how to write, get published and earn an extra income.

'Most people can be taught to write for publication,' claims Susan Busby, Head of Britain's largest writing college, 'as long as they want to write, are willing to learn and put in the time and effort required. Our students prove that. They come from all walks of life and have very different educational backgrounds. Yet, after studying with us many will see their name in print for the first time.'

The Creative Writing course offered by The Writers Bureau covers all genres – articles, short stories, novels, books, scripts etc. so students get a chance to explore all types of writing to find where their interests and talents lie.

Students also receive individual, personal tuition from a professional writer who gives guidance on style, technique and marketing.

'The course gives a student confidence in their work and the know-how to increase their chances of publication,' explains Susan. 'Unfortunately, the untrained writer is more likely to have their work returned to them, not because they can't write, but because they haven't followed the rules of the publishing world. And that, in a large part, is what we teach – how to make your work acceptable to those who will pay for it.'

The college also provides a whole support system to novice writers that includes their tutors, their advisors, free resources and chance to converse with other writing students on their website.

The Writers Bureau is so confident in the training and support it provides that it gives an amazing money back guarantee – if a student doesn't earn their fees back through published writing by the end of their course the college will refund them in full. Plus, the course comes on 15-day trial so you can see for yourself the quality of the training on offer.

To find out more about how The Writers Bureau can help you become a successful, published writer contact them for a free prospectus:

- 0800 856 2008
- www.writersbureau.com

Please quote ref: JL26516



Published



Rachel Dove "I won the 2015 Flirty Fiction Prima Magazine and Mills and Boon competition. The prize was £500, a three page feature in the magazine and the chance to work with Mills and Boon on my book which comes out in April 2016."

"Also I have three stories in three anthologies with other authors – we've raised almost £2,000 for cancer charities"

Published



George Stewart "I am delighted to tell everyone that the course is everything it says on the tin, excellent! I have wanted to write for years, and this course took me by the hand and helped me turn my scribbles into something much more professional. I am delighted that **my writing is being published and I am actually being paid**. All thanks to the Comprehensive Creative Writing course."

Published



Katherine Kavanagh "I have been publishing my own niche website for circus critique. This work has led to recognition in my field, with work offers ranging from writing book reviews for scholarly journals to running master classes for young people. I have had two paid writing residencies at festivals this year and have been employed to write tweets. Payments total £2575, plus expenses for travel, tickets to events and payments in kind in the form of review copy books."

Published



Kris Roberts "When I first saw my words in print it was life changing. Someone else had read my work, believed in it, paid for it, and put it out there for others to see. As more articles made it to press, my confidence grew and I found I wanted to inject some of myself into my writing. At the time of writing this I have received £1,197 for my work."

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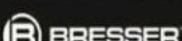
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"My patients come in miserable and go out smiling. It's incredibly fulfilling to be part of that"

Peter Whorwell tells **Helen Pilcher** about his passion for medicine, and why IBS deserves to be taken more seriously

I've always been interested in how things work. When I was 10, I remember buying a book about viruses and then puzzling one of my teachers by asking whether mouse viruses could cause human cancer.

I used to make rockets. When I was a child, you could buy all the ingredients to fuel a rocket from the chemist. I'd then ignite it remotely from the house using an electric current.

I always knew that I wanted to do medicine. I used to watch the TV show *Dr Kildare* where the lead character would roam around in a white coat comforting patients. When asked why I wanted to become a doctor at my interview for medical school, I said that *Dr Kildare* was my inspiration. I was just being honest. Much to my relief, they accepted me.

I didn't really enjoy my medical training. We saw a lot of patients but I was disappointed to find some of the consultants arrogant and lacking in empathy. It didn't put me off medicine but made me determined that I would do things differently when I qualified. When I did qualify, I transformed from a lazy, rather disillusioned student into a workaholic who has never stopped 'drinking' from the cup of medicine.

Generations of medical students have been taught that irritable bowel syndrome (IBS) is a largely psychological condition, but it's not. I treat people with severe IBS. They suffer extreme pain, many have faecal incontinence and more than a third have contemplated taking their own lives. I'm proud of what I've done and what I can do for these patients. I've published over 300 papers on IBS, all of which have helped to put the condition on the map. The result is that doctors are now starting to take IBS more seriously.

I can help, but not cure, almost everyone who comes to my clinic. We explore diet and medication, and sometimes offer hypnotherapy. My research has proved, beyond doubt, that hypnotherapy can help people with IBS. We help give people their lives back. My patients come in miserable and often go out smiling. It's incredibly fulfilling to be part of that.



I don't have any hobbies. I don't read novels. I hardly watch TV. The well-being of my patients is incredibly important to me. I live and breathe medicine.

If I wasn't a doctor, there's a chance that I might have become a pilot. I learned to fly when I was a registrar, but I no longer fly. Still, I can't stop myself staring at a plane when one goes by.

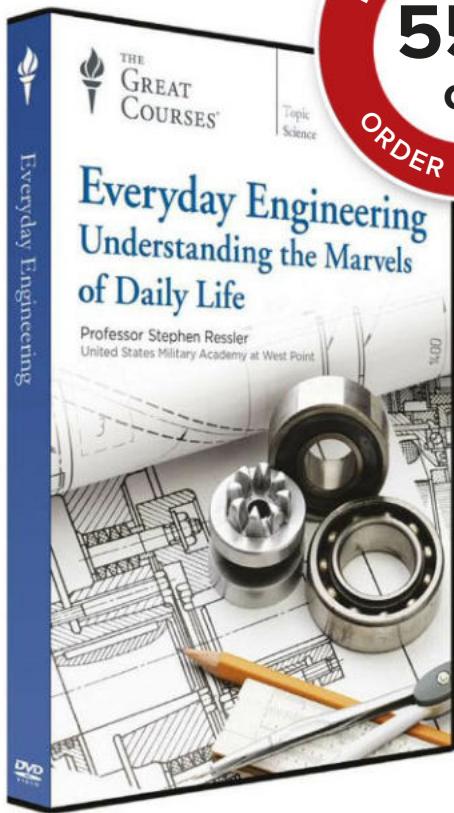
Peter Whorwell is professor of medicine and gastroenterology at the University of Manchester.

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